CERAMICS

MAY
1951

27 Vol. III

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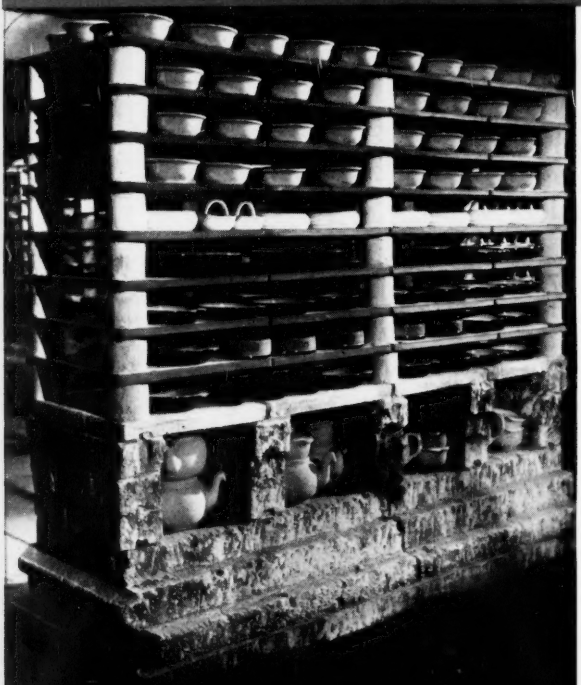

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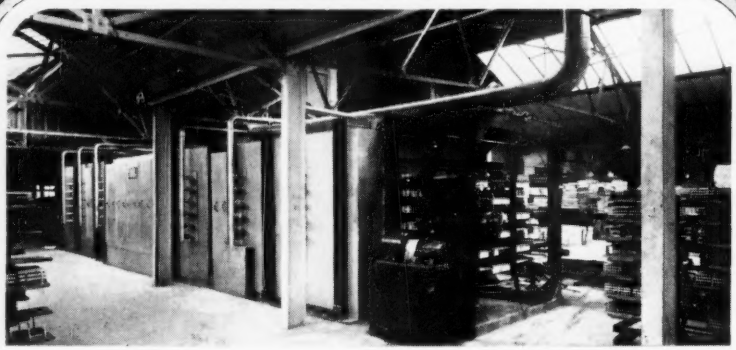

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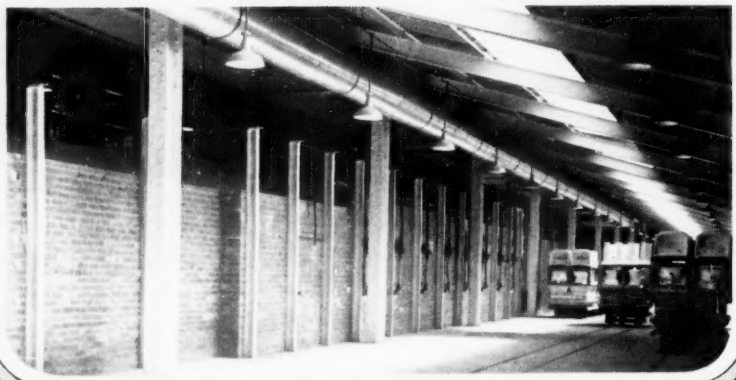

Littler

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CERAMICS

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Ceramics

VOL. III MAY, 1951 NO. 27

SOUTH BANK

THE 1851 Exhibition was heralded in by doleful thoughts—yet it had a site area of 21 acres, 14,000 exhibitors, six million in attendance and made over £200,000 profit in its own right, apart from its prestige value.

Thence onwards the story of vast exhibitions was one of continued loss. Wembley dropped a million and a half pounds from 1924 to 1925. Yet it was an Empire Exhibition in the real sense of the word.

Of course the Council of Industrial Design is optimistic to the extent of forecasting that 5s. spent on their book *Design in the Festival* will be worth £5 in 2051—but by then our troubles will be over!

The difference between this Exhibition and all others is that the latter were staged with the object of selling things. This one is cultural in the true sense of the word, for indeed poor deliveries, likely to get worse, rob it of any sordid commercial aspect.

Even deliveries abroad are stretched to breaking point and we can sell all we can make with the limited amount of raw materials Harold Wilson left in the larder before he decided it was time he gave up his job.

Yet Gordon Russel, the Festival Director, said recently in *The Times*—"I claim that there has never been before a series of selective exhibitions on this scale . . . and where so much time and care was given to putting it into operation . . ." So the Festival Boss is happy.

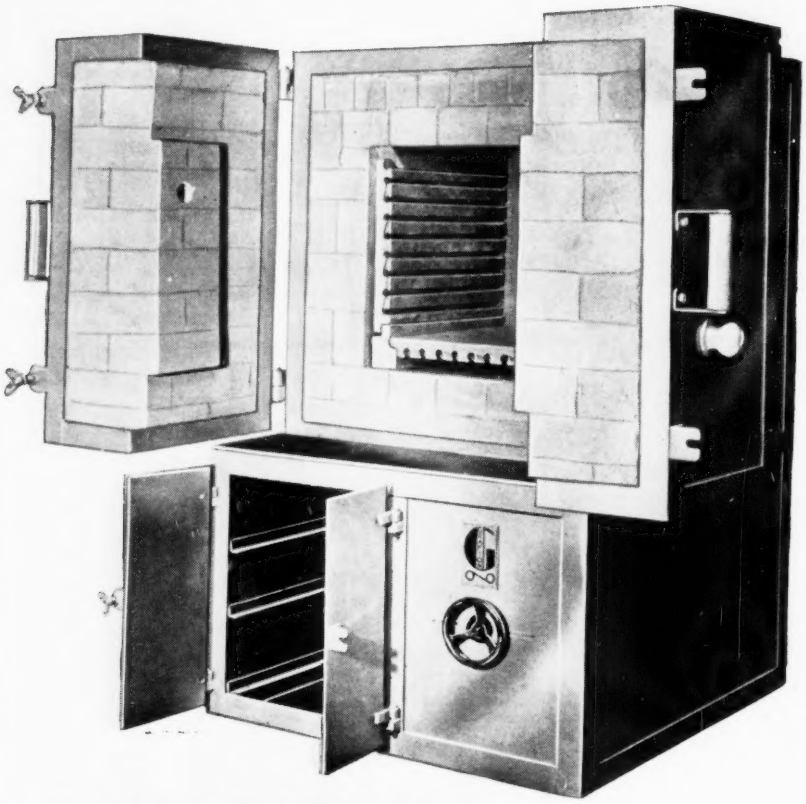
Indeed the British sense of humour is beyond foreign comprehension. We are short of food, short of accommodation, short of raw materials, subject to power cuts, subject to an economy budget and yet—we have an exhibition. We set out to attract the world to our shores to partake of our genteel poverty.

Of course a thing like this show once started cannot be stopped and obviously once started we must do the best we can to make it a success.

Culturally the South Bank is just what would be expected from a number of designers given their head for the first time, to produce their best with cost as relatively of no importance. Lucky men. Few indeed in any craft or profession get such an opportunity.

It is a real prestige show for Britain and prestige advertisement is always expensive.

A pity they could not manage to illuminate "Our Herbie" cast in plaster or cement seated on the uppermost point of the "skylon!"



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COMMENT

by **ARGUS**

MY criticism of our present university system of training recruits for industry has brought occasional verbal attack, although I still await a logical case against these criticisms on paper!

There is space available to any who are prepared to defend the present British traditional pure science faculty monopoly of the training of executive entrants to the various industries.

I have criticised the tendency for research to be too unrealistic. I think a disproportionately low proportion of D.S.I.R. and related research is directed towards the commercial exploitation of existing knowledge. I still offer space for the publication of views to the contrary.

Supporter 1

Recently support for the latter contention was forthcoming from Sir Ernest Canning, a former Lord Mayor of the City of Birmingham and the chairman and managing director of W. Canning and Co. Ltd. the well-known suppliers to the electroplating trade. In an address to a conference in Torquay he made this statement: "In my time I have seen the recruitment into plating of bands of chemists, and when I see them scratching their heads and cogitating on most intricate problems which do not always result in solving the problem, I wonder sometimes how some of us make a profit at all." He continued: "Science in the abstract is as great as Diana of the Ephesians and as adorable, but it is applied science that benefits the material world and provides its bread and butter."

Supporter 2

Some time afterwards I heard Sir Frederick Handley Page speaking on behalf of the guests at the Annual Luncheon of the Institute of Fuel. He stressed the former contention that too few people recognise the supreme importance of industry as the sole earning capacity of the country and he called for the trade associations and those interested in industry to do something towards imparting some realism into our training of young people for industry.

Here are two men, both of whom have contributed extensively towards the development of businesses in the fields of metal protection and aeronautics. Maybe they have made fortunes, but likewise they have contributed directly to the Nation's wealth and by taxation to the Chancellor's balance sheet! How happy indeed would the Nation be if the salary of the chairman of this National Board or that were doubled or quadrupled providing that he made a similar successful contribution to the Nation's wealth-earning capacity.

Self-Preservation

The trouble with a planned economy is that it presupposes that every cog in the human wheel will mesh closely and uniformly; it presupposes the existence of a majority of human beings who have the interests of the State at heart and are prepared to subjugate their innate selfishness for the benefit of mankind. Whether or not such a world would be an ideal one in which to live raises many arguments of a philosophical nature, but the stark

reality is that every human being is dogged by the strongest primeval instinct which is self-preservation. And self-preservation leads directly to a greater or lesser amount of innate selfishness. Thus it is that one has to face the selfishness of mankind and it is upon that particular point that the grandiose plans of the social reformer have become continuously unstuck for thousands of years.

Of course a scheme of free National Health is well worth while in theory, but in practice we know of the time wasted by doctors on selfish people who see him unnecessarily. We know that there was a tendency for folks to say "This is free, let me get my whack and the Devil take the hindmost." We know that the worker in the basic industries in the years between the wars was very often unfairly treated —steel, coal, shipbuilding, pottery and so on. There is no doubt that the standard of living, at least until 12 months ago, was steadily rising among the lower income groups. However, anyone, be he a manager, a trade unionist or a factory owner, must confess that there has been a tendency for many to try and get as much as they can for as little effort as possible.

Subsidy for Inefficient

Unfortunately, the planned economy has not benefited the able and the diligent in the productive industries so much as it has subsidised the inefficient and the slacker. It has made fortunes for many non-productive industries in the retail cash trades, bookmaking, the amusement industry, football pools, and so on. Merchants who have bought and sold anything from tintacks to grand pianos with wads of notes still escape the net. However, the salaried officials in a productive organisation dealing with a cheque trade and not a cash trade, have been penalised all along the line.

We know that the social reformers set out with the laudable intent of the State taking over control and ensuring that the profits, if any, would be diverted to the State coffers. Yet there still prevails in the various nationalised Boards and in the Civil Service, a kind of petty bribery. The free luncheon, the odd bottle of Scotch, the box of cigars, theatre-tickets and so on *ad infinitum*. They do not add up to much and no one is suggesting that there is bribery in the true sense of the word, yet the fact remains that in the State envisaged by the social reformer, such actions would not take place at all!

I met two Civil Servants from a Government department recently in the Midlands. They were up to question the conformance of a certain article to specification. Certainly after the lunch they enjoyed they were in no fit state to lay down a policy with that strict impartiality one would expect.

I am not blaming them!

I am not blaming the firm in question for everyone is a human being, but I merely use that as an argument to point out that with best will in the world humanity cannot achieve that strict impartiality upon which the social reformer bases his arguments.

Sinecure Appointments

We have to confess that there have been many sinecure appointments in private industry in the past such as guinea pig directorships or jobs offered because of the family or as a result of marriage to the daughter of the family. But today the same thing still prevails except that it is a friend of the M.P. or a pal of the boss of the State Board. The same frail human nature is operating and for Heaven's sake do not let us imagine that chicanery disappeared the moment that the Flag of State was hoisted over an industry.

Indeed it often worsens because at least a private industry, if it does not make a profit at the end of the trading year, is in Carey Street and the jobs of the men in jeopardy. However, in nationalised industry any loss is passed over to the taxpayer or to the consumer next year in the form of increased prices. The point is that the responsibility of management in a nationalised concern is less, and therefore there is not that same necessity to pursue an efficient policy nor are jobs all along the line necessarily lost as a result of this inefficiency. Obviously then, State control offers an even greater chance for petty chicanery in offering appointments for political purposes.

Fallacy of State Control

This is not written churlishly. The sincerity of the social reformer and his burning zeal is respected and admired, but one is forced to point out to him how, with the human material at his disposal he often opens up new avenues for the "wide boys" to cash in. The fallacy of nationalisation and State control is that where there is direction of an industry without responsibility the end must be disaster.

Surely these are potent facts which cannot be ignored.

The Miner's Pension

In so far as the Welfare State one can observe chicanery in the allotments of its bounties. The social services have been used largely as a vote catching attraction.

One hears that poverty has disappeared from this country yet the Acton Society Trust have just produced a booklet under the title *The Miner's Pension*. They have made a case study of a village called Maerdy with a population of 4,000 at the head of the Rhondda Fach Valley, an area which was badly hit during the depression. Something like 94 per cent. of its old-age pensioners have been miners at one time or another. They live where, to quote the pamphlet "the Workman's Hall is the largest building in the place. A football pitch, bowling green and two tennis courts cater for the sportsmen. There are seven chapels and a parish church . . . a number of small shops, a public house, one café and two fish and chip shops. . . . The old-age pensioners rarely go outside Maerdy . . . there are no cheap travel rates for old people. . . ."

Income and Expenditure

Of the 153 men over 65 only 6 per cent. were still working. Of the total sample, about half had not earned money during the last 15 years and the average age of this group was nearly 72, so that they had been unemployed for more than 9 years before reaching the retiring age. Of this 153, 130 either took in lodgers or lived as lodgers in somebody else's house. The weekly income for couples from all sources ranged from £2 2s. to £2 13s. 6d. Rents varied from 9s. to 13s. 9d. You can be a lodger at about 5s. a week, buying your own food or pay 18s. to £1 covering board and lodging. The people there had one source of heating, coal for everything, and expenditure on coal accounted for 7s. 4d. a week, for they cannot afford electricity at 1s. a unit. Clothes were a constant problem. Many cannot afford visits to the cinema or a radio licence. Only by cutting down on food was it possible to leave a margin for clothes, household replacements and the like. Many made the comment "they can find money to give family allowances and money to raise the pay of soldiers, but they cannot find any to raise the old-age pension."

Frankly, the present Government has misrepresented the Welfare State proposition, and they have used their large number of statisticians, to ensure that the "welfare" is meeted

out to those sections of the population which carry the largest voting power. In this village of Maerdy, out of a population of 4,000 there are something like 165 who are despised and rejected of the Welfare State. And this is one tiny example!

Is This Social Reform?

The point is that the cost of ensuring that old people have a reasonable standard, is relatively small because they are a relatively small part of the population. But because they are a small part of the population they carry a small voting power and the Welfare State withholds from them that which they have earned by virtue of their age. Is this Welfare or Social Reform or is it an inverted form of political bribery and corruption?

If this is the present Government's political interpretation of Welfare, the means test of the 1931 depression was a luxury by comparison! Then, an unemployed man and his wife got 26s. a week, but the pound then had a buying power of about £4 today.

See what I mean about the social reformer starting off with his burning zeal, but leaving the politician to use chicanery, innate selfishness and so on to guarantee his return at the polls.

The fact that there is one place like Maerdy makes a travesty of the Welfare State.

Likewise one discovers that the Welfare State offers little for that part of the population which has not reached the age of 21. They carry the National Service. They are crowded into schools which are worse in terms of building and class size than they have been for 25 years. It is the parents who draw the family allowance and the centres where they can park their children benefit the parents. But then of course it is the parents that have the vote!

As long as you have a vote and are representative of a section of the community which carries a large voting power, the Welfare State will see you well as long as it can but Heaven help you if you are either very young, very old or disabled.

When individuality is subjugated to organised State Worship, the worst in mankind—and there is plenty—comes to the fore!

INDUSTRIAL SAFETY—BIRMINGHAM EXHIBITION

THE Birmingham and District Industrial Safety Group has organised an exhibition to be held from 30th May to 2nd June, 1951, in the Bingley Hall, Birmingham.

More than fifty stands will be occupied by firms manufacturing industrial safety and factory welfare equipment including all kinds of machine guards, fire fighting appliances, protective clothing, goggles, etc. This is the first large scale exhibition dealing with industrial safety to which the factory worker will be invited in addition to all grades of factory supervision, from chargehands to works directors.

Exhibitors are drawn from all parts of the United Kingdom.

The members of the Birmingham and District Group will be exhibiting ideas which they have developed and used in their own factories, and a large composite stand will be devoted to this aspect of non-trading exhibits. A temporary building is being erected within the Bingley Hall where various films dealing with safety, welfare and hygiene will be shown from time to time during each day.

Believing that the doctrine of safety cannot be inculcated too early in life, arrangements have been made for senior students of secondary schools in the Midlands to visit the Exhibition as well as students from the various Technical Colleges, etc.

Further information regarding the Exhibition can be obtained from the honorary secretary, Mr. A. G. Cogswell, c/o Dunlop Rubber Co. Ltd., Fort Dunlop, Birmingham 24. Catalogues (price 1s. 3d. post free) can be obtained from the same address.

Some Troubles in Vitreous Enamelling

(SPECIALLY CONTRIBUTED)

WORKERS in sections of the ceramic industry which employ firing temperatures of 1,100° C. and over often envy the vitreous enameller whose products can be fired comparatively quickly at temperatures in the region of 800-900° C. On the other hand the vitreous enameller must often envy the potter his non-metallic biscuit ware, when he considers all the troubles that may arise from having to place a layer of enamel firmly on a metallic sheet or casting.

This article is an attempt to show that many of the faults which beset the potter are found in a similar form in vitreous enamels, and that there are, in addition, certain others peculiar to this industry.

Metal Must be Cleaned

Most people will be familiar with the fact that the metal to be enamelled is cleaned either by chemical methods or by shot blasting and then the enamel is applied—usually nowadays by spraying. This is then dried and constitutes what is called the "biscuit." In this respect it differs from potters' "biscuit," since it has not been fired but merely dried. Subsequent firing melts the enamel on to the ware.

To promote a good bond between the enamel and the metal it is usual to first fuse a ground coat on to the metal. This consists mainly of borax, felspar and quartz with small additions of oxides of cobalt, manganese and nickel. The cover coat or coats are subsequently fired on this ground coat. It will be evident that, since enamels resemble glazes, many of the faults found in pottery firing will also be found in enamelling, and some of the causes will be similar.

Crazing Due to Unequal Expansions and Contractions

As with pottery crazing arises from unequal expansion and contraction of the metal and enamel, and it may appear as parallel lines or in spider web formation. It is distinct from strain, or hair lines, in which the surface of the enamel is not broken. Crazing can occur immediately or after the ware has been in service, just as with pottery. Thick coatings are more liable to the fault than thin ones as with glazes, and delayed crazing is most likely with those parts of the finished ware which are subjected to thermal shock. As with vitreous pottery bodies, the cure is to compound an enamel (or glaze) of similar expansion to the underlying medium. As a further safeguard the contraction of the enamel in cooling is made smaller than that of the metal so that the enamel is in compression. This is of course common practice with pottery too. As with glazes it is possible to evaluate expansion factors for enamels which make it possible to calculate expansions in an approximate way and these serve to estimate differences in expansion between enamels of the same type (cf. CERAMICS, April, 1951, p. 74).

Hair Lining

This fault must not be confused with crazing since the finished enamel coat is not fractured. It usually occurs on sheet iron enamels as a series of dark lines where the

undercoat shows through the cover coat. The defect is also seen occasionally on cast-iron parts. With holloware a white hair line is sometimes seen. This is more in the nature of a depression or break in the succeeding coats of enamel, when one has already fused completely over the ground coat. Hair lining may or may not be a cause for rejection, depending on the degree to which it disfigures the ware.

Causes of Hair Lines

The causes of hair lining are those which bring about cracking of the enamel coat and the extent to which it shows on the finished ware depends on the degree to which the fracture heals over by subsequent fusion of the enamel. Those enamels which are less fluid at the kiln temperature may be expected to give deeper hair lining than others.

The cracking of the enamel coat is likely to be caused by:

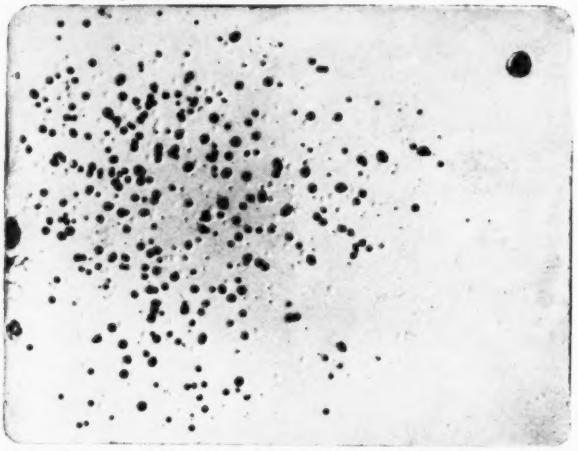
(a) careless handling of the parts, e.g., sheet panels;
(b) uneven thicknesses of metal causing differential heating, e.g., around welds, seams and flanges or at points where ware is held by relatively cold tools in the furnace;
(c) buckling of the metal in firing;
(d) heavy application of the enamel causing it to crack in drying and firing, and also making it more difficult to heal over the deep crack so caused.

Easy firing of the ground coat is stated to accentuate the fault.

Blistering

As with ordinary ceramic glazes this fault is caused by a gas evolution when the enamel has begun to melt. In the normal way in enamels the large bubbles of gas should escape and the craters caused heal over by subsequent melting. All glazes and enamels go through a period when the surface is thrown into craters due to evolution of large gas bubbles from the underlying body or metal, and from the enamel or glaze itself. If for any reason these do not escape then blistering will occur. The term blisters in the trade is often reserved to bubbles over $\frac{1}{16}$ in. diameter up to about $\frac{1}{4}$ in., smaller bubbles up to about $\frac{1}{16}$ in. diameter occurring in the enamel are referred to as "boil." Obviously the escape of gas will be hindered by:

(a) thick coats of enamel;
(b) underfiring so that the enamel is too viscous for gas bubbles to escape easily.



An example of blistering

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Contamination with organic matter which does not burn out readily before the enamel begins to melt is also a possible cause such as dirty metal. Other practical causes are incomplete firing of one enamel coat, so that on subsequent firing gas is liberated and blisters the coating above, firing at too low a temperature or not allowing sufficient time for the gas bubbles to escape and for the cavities to heal over, and dirt contaminating the enamel. Gas inclusions in the metal may also be a cause of blisters. Annealing should cure this.

Reboil

This is the result of gas evolution from the metal through the ground coat during firing of the cover coat, and it results in small black specks in the coat or even bare spots in it through which the ground coat shows. There are available now steels which do not give this trouble. It is possible to minimise the effects of boiling by using a cover coat of such fluidity and opacity that any scars due to reboiling are covered over in the later stages of firing. The use of a ground coat which readily allows the gas to escape is also an advantage.

Jumping and Popping

Jumping describes a process in which the enamel is blown off exposing the iron underneath. It has its counterpart in the shelling off of glaze over colours in pottery. The cause is the same in both cases, namely an imperfect bond between the base and the enamel or glaze. This may be due to rust, dirt, grease, etc., on the metal prior to enamelling and the remedy is obvious.

Popping describes the jumping off of the cover coat leaving the ground coat. It appears to be caused by

blistering of the ground coat. It is believed to be due to the metal used, as some batches can show popping, and others be free of the defect under similar operating conditions. Where more than one cover coat is used the effect of popping can often be covered in subsequent firing.

Chipping

This fault is the flaking off of pieces of the enamel. It usually occurs at the edges or over welds and seams and it is aggravated by the application of thick coatings. Carelessness in assembly may also set up strains which can cause chipping. Underfired ground coating, giving poor adherence to the metal, can also produce conditions favourable to chipping. As in "peeling" in pottery a gross misfit between body and glaze can also cause the fault.

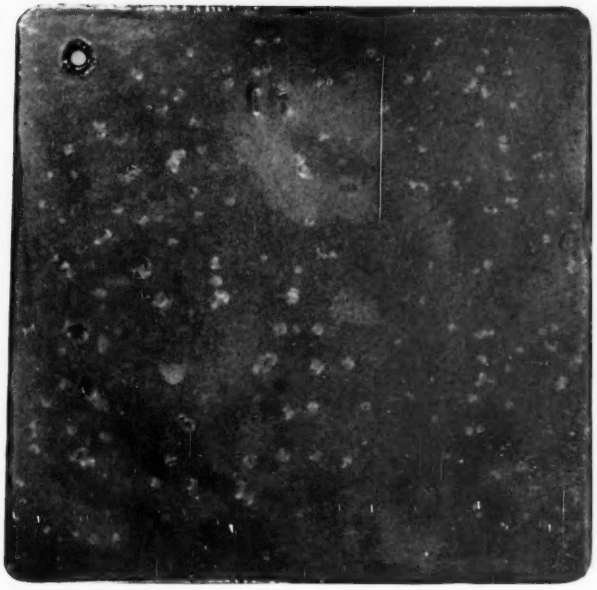
The remedy is usually to avoid heavy enamel coatings and to design parts for enamelling so as to avoid sharp corners. A minimum radius of curvature on an article of $\frac{3}{16}$ in. is recommended.

Crawling (Tearing)

This defect resembles that encountered by the potter and tearing is really a severe case of crawling. The causes are similar. They involve conditions in which the glaze or enamel rolls up under the action of surface tension in the molten state leaving the undercoat exposed.

Anything which conduces to cracking of the enamel coating before firing may set up crawling. Thus too rapid drying such as putting the damp ware in the furnace may set up cracking leading to crawling. Bending of the coated sheet iron either by bad handling or by buckling in the furnace may also crack the unfired enamel coating. Spraying on dirty metal can also give the fault as the enamel does not adhere properly. Handling with clean gloves is advisable. As with glazes overgrinding of the enamel can also set up crawling. Excessive

An example of orange peel



An example of fish scales

amounts of B_2O_3 in the mill liquor tend to exaggerate the fault. Addition of sodium nitrite it is said will often eliminate it.

Orange Peeling

As its name implies this is a condition in which the enamel surface is rough. The usual cause is spraying with excessive air pressure or with the gun too near the surface of the ware. It can also be caused by underfiring or the use of enamels which are very viscous when molten. The effect is the same namely that the enamel is disturbed by the normal escape of gas in the firing process and the surface has not been able to heal over completely in the subsequent heating.

Grinding the enamel a little finer may help in this direction provided it does not cause other faults. The first remedy to be tried, is however, an adjustment of the spraying conditions.

Fish Scales

This fault leads to the flaking off of crescent shaped chips resembling fish scales from the cover coat. It may occur during the process or be a delayed effect. It is a fault originating in the ground coat, but may not appear till the cover coat is added. The defect does not occur on cast iron. Many causes have been described and a complete explanation has yet to be given.

Three types may be recognised (a) large scales, (b) medium or "process fish scales," and (c) small scales or "shiners." The latter is a sheet iron ground coat defect. These fish scales are minute and resemble tiny diamonds under reflected light.

Generation of Hydrogen from Base Metal

One theory is that the cause is the generation of hydrogen from the base metal during or after cooling of the ware. Some metals show a greater tendency to fish scale than others.

This can be checked by using the same enamel on different metal samples. Incorrect firings of the ground coat may also produce conditions favourable to fish scale.

Underfiring is said to favour delayed fish scale. Overfiring may cause "shiners." The latter may cause "pop off." Faulty pickling may also lead to poor bond development between metal and enamel with increased tendency to fish scale.

These are considered the main causes. For others the reader is recommended to consult *A Manual of Porcelain Enamelling* (Cleveland, Ohio, 1937).

Copper Heads

These refer to small areas in the fired ground coat having a coppery appearance. They arise from gas evolution through the ground coat exposing the metal underneath which oxidises, or possibly areas of dirty metal to which the enamel cannot adhere. The metal itself may be exposed or the oxide may combine with the frit to form a slag left in a crater.

Some samples of metal are more prone to gas evolution than others. The use of a hard frit, and one which can dissolve only limited amounts of iron oxide will make it more difficult for the ground coat to heal over broken bubbles and to cover up patches of oxide. Softening the enamel by addition of borax can sometimes help in this respect. Thin application of the ground coat makes copper heading more liable to occur as would be expected from what has been said above. Excessive amounts of combustion products in the furnace atmosphere may promote corrosion of the metal and favour copper heading.

Sometimes the ground coat appears to burn away leaving a film of coppery or metallic appearance. In this case the enamel is saturated with iron oxide and the remedy is to use a harder firing ground coat frit in the mill mix.

Rust Spotting

When ware is dried after application of ground coat, particularly if dried slowly, rust coloured spots sometimes appear which may cause copper heading. The fault is more likely where the ratio of alkalis to B_2O_3 is high and an addition of boric acid is stated to improve matters. The more popular cure, however, is an addition of sodium nitrite (of the order of $\frac{1}{16}$ per cent.).

Scumming

This describes a dull appearance in the fired enamel. The causes are similar to those encountered with glazes. Devitrification or crystallisation of the enamel may be due to errors in composition, or to the firing cycle. Sulphate formation on the surface of the enamel due to the presence of sulphur gases in the kiln are another potent cause, especially if ventilation is poor. Since enamels are normally fired and cooled quickly, the furnace atmosphere is probably the more important cause of scumming.

Shore Lines

These are a surface defect in the form of a series of parallel wavy lines or troughs in the surface of the cover coat enamel. It resembles the furrows set up on a sandy shore by water ripples and is more common with acid-resisting enamels. During drying it appears that periodic precipitation of salts from the enamel occurs and these exert a fluxing action on the enamel causing the lines. The fault is accentuated by rapid drying. Precipitation of the salts can often be prevented by increasing the viscosity of the enamel by addition of saturated solutions of such substances as salt or sal ammoniac which coagulate some of the colloidal material. This technique is familiar to the potter for controlling the properties of ceramic glazes.

REFERENCES

1. *Vitreous Enamels*, Borax Consolidated Ltd., London.

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2. *Manual of Porcelain Enamelling*, edited by J. E. Hansen, Cleveland, Ohio, 1937.
3. "Enamel Process Defects, Causes and, Possible Cures," M. E. McHardy, *Ceramic Industry*, 1948, 1949 and 1950 (series of articles).

PROTOLITE LTD.

AT the recent Gauge and Tool Exhibition held at the New Hall, Vincent Square, from the 15th to 25th May, 1951, Protolite Ltd., Central House, Upper Woburn Place, W.C.1, showed a comprehensive range of products in the well-known "Prolite" cemented tungsten carbide (i.e., hard metal) and it was interesting to note the many varied applications for which hard metal are now used. Besides tipped turning tools, drills, reamers and milling cutters, there were of especial interest to tool makers, jig boring cutters, press tools and press tool segments, gauges and gauging anvils. A special feature of the exhibition was the flow sheet, showing the stages in the manufacture of hard metal from its introduction as a basic mineral to its despatch as a finished tool. This was illustrated on a wall display, the processes of manufacture being dealt with more extensively in the Murex 16 mm. colour sound film "Hard Metal," which is available for loan on application. Other applications on view were wire, tube and bar drawing dies, pottery tools, button making tools and a large range of block cutters, planer blades, saws and routers for the woodworking industry. The manufacture of small turned parts has been assisted by the introduction of solid and split steady bushes and feed fingers as well as a range of tools for use on Swiss type automatic lathes.

For some while Protolite Ltd., have also supplied rolls for wire flattening and circular slitting cutters for sheet, examples of which were shown on the stand.

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DRYING OF REFRACTORY MATERIALS*

by

A. L. ROBERTS
B.Sc., Ph.D., F.R.I.C., M.Inst.F.†

ALMOST without exception, refractory and ceramic masses in the unfired state must be mixed with water to obtain a plastic material, which can then be moulded to the required shape. The amount of water added varies within considerable limits, dependent upon the particular material and the moulding process used; it ranges broadly from about 5 per cent. for the "semi-dry" pressing methods to about 20 per cent. for the slip-casting process, in which articles are formed by pouring a water suspension of the refractory into a suitably absorbent mould.

Essential Stage

Before they can be fired, ceramic masses must be dried to a low residual water content to avoid shrinkage-cracks or bursting from steam developed in the material. Drying is thus an essential stage in the manufacture of ceramics and can be regarded as one of the unit operations of the industry. In general, the process is best carried out separately from the firing, although it is often performed in the kiln itself. Continuous chamber kilns with low initial rates of heating can often be used satisfactorily for drying, especially when dealing with refractory materials of comparatively coarse and open texture.

Faults Originate at Drying Stage

In many respects, drying is probably one of the most troublesome operations in the production of refractories, especially where large or awkwardly shaped ware is concerned. It is common knowledge that many of the faults found in the fired product (cracking, warping) often originate in the drying stage. The essential reasons for the particular sensitivity of these materials to drying are (a) the shrinkage which accompanies the removal of water during the constant-rate period, and (b) the fact that the conditions needed to promote drying tend in the main to set up moisture-content gradients giving rise to differential shrinkage stresses in a comparatively weak material. Shrinkage is the main difficulty, although in the special cases of refractories containing lime or magnesium oxides expansion may occur owing to accelerated hydration on heating, a rather unusual consequence of attempting to dry a material.[1]

Much Fruitful Research

The industry has always been acutely conscious of the careful control of drying conditions needed in most circumstances; in turn, the mechanism of drying is recognised as of prime importance and has been the subject of much fruitful research directed towards the practical aspects of drying, and the design of

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* This paper has been contributed, at the invitation of the Institute of Fuel, to a symposium under the general heading "A Study of Drying," which is being conducted during the 1950-51 Sessions.

† Livesey Professor and Head of the Department of Coal Gas and Fuel Industries with Metallurgy, University of Leeds.

dryers, as well as to a better understanding of clay/water relationships.

Theory of Drying

The classical presentation of the theory of drying has already been adequately discussed by Hendry and Scott[2] in the first paper of this series, and it will suffice here to state that the data for refractory and ceramic bodies usually show the general features associated with the drying of porous solids. Fig. 1a shows typical rate-of-drying curves determined by H. H. Macey[3] for clay cubes of different sizes and with an initially high moisture content, indicating clearly the periods of constant-rate and falling-rate. The critical moisture content, which marks more or less sharply the transition between the two stages, is found to correspond approximately with the cessation of shrinkage; at the most, shrinkage during the falling-rate period is small enough to be neglected for practical purposes. Fig. 1b shows shrinkage data for one American (A), one British (B) fire clay and one British ball clay (C); the last is of very small particle size and appears to show a slight expansion rather than contraction in the secondary stage. Since the size distribution of particles in ceramic masses, and in clays themselves, is wide, sharp definition of the critical point would not be anticipated, because of secondary shrinkage following the coalescence of the largest particles.

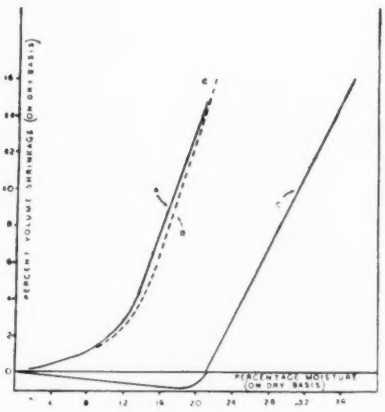


Fig. 1a. Shrinkage curves for neat fire clays

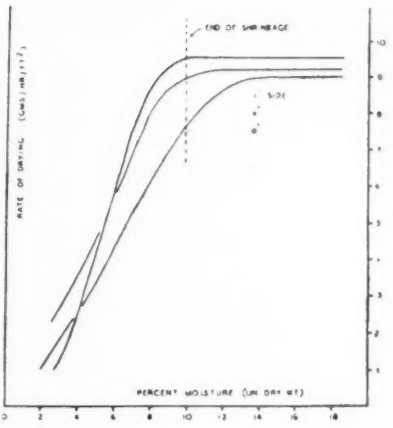


Fig. 1b. Rates of drying of fireclay grog cubes of different sizes (after H. H. Macey[3])

The Constant-Rate Period

It is the constant-rate period which is of main concern in ceramic drying, because of the dangers of cracking which accompany the shrinkage in this range. Once the *whole* of a clay mass has passed into the falling-rate stage, the danger of cracking is over; the transition shows itself clearly by a change from the dark colour of the constant-rate period (due to the continuous surface-water film) to a lighter colour when the continuity of the water is broken. At this stage the clay also becomes "leather-hard." Drying down to the final equilibrium moisture content is in practice difficult, unnecessary and even undesirable, as completely dry clayware may be too brittle for safe handling.

The transition from the constant-rate to the falling-rate period is generally accepted as due to the factors operative for porous solid systems, i.e. the break-up of the continuous water films, the recession towards the interior of the surface moisture, and the formation of discrete drops within the structure of high curvature and reduced vapour pressure. The rate determining process in the stage is the transfer of water from the interior to the surface, which becomes more and more dependent upon diffusion of vapour than upon capillarity as the drying proceeds. Other factors, however, which are probably peculiar to clay drying, also contribute to the slow drying period. Ceramic bodies based on clays contain a substantial proportion of particles of colloidal dimensions, which tend to be carried outwards to the surface by the active capillary diffusion of water during the constant-rate stage. The tendency of this is to seal up (or case-harden) the surface of the material and so further to impede the passage of liquid water or water vapour. It is an effect particularly noticeable in slip-cast articles in which, prior to the drying proper, some water has been removed from the body by capillary action of the porous mould. In addition, the clay minerals themselves strongly absorb water, either on the surface or within the crystal lattice according to the type of mineral. Under normal drying conditions such water can be removed only at temperatures in excess of 100° C. (212° F.).

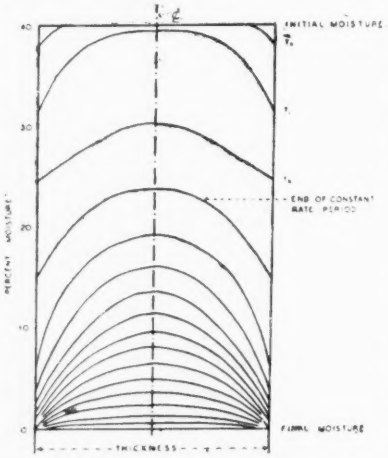


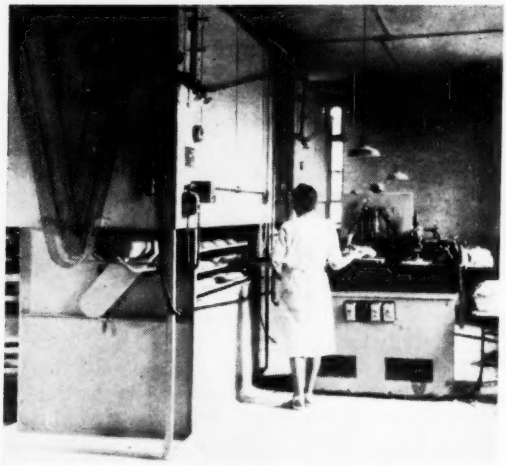
Fig. 2. Diagrammatic representation of clay slab

During the constant-rate period water is transferred by capillary diffusion to replace that evaporated at the surface, whilst simultaneously shrinkage takes place. The water movement means that a moisture-content gradient is set up between surface and interior, depending in extent on the texture of the body (the size and irregularity of the capillary channels) and upon the actual moisture content. Since the shrinkage is directly dependent upon moisture content, it follows that differential stresses must arise between adjacent portions of the drying material and that cracking will occur if the stresses exceed the ultimate strength of the material. These conditions are essentially the same as those which arise during the sudden heating or cooling of solids, in which differential stresses, which cause cracking if they exceed the ultimate strength, are set up as the result of temperature gradients.

The moisture-content distribution in a drying mass is therefore of prime importance. The classical work of Gilliland and Sherwood[1] has shown that the distribution for simple shapes during the constant-rate period can be calculated from the diffusion equation

$$\frac{dM}{dt} = K\frac{d^2M}{dx^2}$$

which of course is the same as for heat flow. In the present case M = moisture-content concentration per unit volume, t = time, x = distance from surface, and K = diffusion coefficient. The moisture distribution in a slab dried under isothermal conditions on two opposite surfaces can be represented diagrammatically as in Fig. 2. It will



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be seen that the moisture-content gradient is greatest at the drying surface and progressively decreases towards the centre. At the end of the constant-rate period, the surface moisture falls rapidly and the surface moisture-gradient becomes very steep, which is consistent with recession of the surface moisture towards the interior of the material.

Similar distributions in cylinders dried from one end were shown by Troop and Wheeler.[5] It will be apparent that the greatest differential stress will be set up towards the surface and that, if it occurs, cracking due to tension will take place on the surface, which is common experience in industry.

In practice, however, conditions are by no means so simple and the mathematical assessment of the maximum safe-drying rate for a particular refractory mass is difficult, if not impossible. During actual drying, the physical properties of the clay are constantly altering, which at least introduces the probability of a varying diffusion coefficient. Furthermore, practical drying conditions are usually such as to impose a substantial temperature gradient from the surface to the interior of the mass, at least in the initial stages. This in itself tends to produce differences in moisture content of a plastic clay;[6] more recently Vassiliou and White[7] have shown that in moist clay columns under a temperature gradient, a continuous regression of moisture occurs from the hotter to the cooler end and results in a characteristic steep "step" between relatively dry and wet portions of the column. They believe that this distribution results from an evaporation condensation mechanism (or some kinetically equivalent process), evaporation taking place in the hotter and

capillary condensation in the cooler regions. Whilst their work applied more particularly to the falling-rate period, there seems little doubt that temperature gradients must at least tend by this mechanism to increase the moisture-content gradient in a drying material.

Limiting Factor

It is therefore clear that moisture-content gradient is the limiting factor in the drying of the refractory and ceramic ware and that for safe maximum rates of drying, all factors tending to reduce the moisture gradient must be brought into operation. As regards the ware itself, "opening-up" the texture to reduce impedance to capillary flow is an obvious measure and is common practice. For this and other reasons, bodies based on clay must contain a certain proportion of comparatively coarse, calcined material ("grog"), but they must also include a certain minimum of colloidal clay to maintain plasticity and strength.

The widely used hot-floor drying, in which the products are dried by gentle convection of air warmed by steam pipes or waste heat, and also by conduction, represents a compromise between efficiency and safety. It is slow, but this may not be a drawback as the factor limiting the throughput of refractories is often kiln rather than the dryer capacity. On the other hand, in works laid down for continuous large-scale production of standard articles, the large kiln capacity demands much faster drying rates than can be obtained by floor drying, and chamber or tunnel dryers are necessary.

It is generally accepted that, in theory, drying stresses would be minimised if the ware could first be heated to a temperature which was reasonably uniform throughout the mass and in an atmosphere of high relative humidity so as to minimise evaporation. Following this, the humidity should be progressively reduced so as to allow drying to proceed, slowly at first, and then more rapidly as the critical point is approached. Such a process would minimise the moisture gradient, especially because the viscosity of water falls rapidly with increasing temperature; thermal expansion of the mass, though slight, should also contribute appreciably to the same end.

Humidity Dryer

These conditions are approached in the modern humidity dryer, which in principle consists of a long tunnel divided into sections in each of which the temperature and humidity are carefully controlled by automatic regulation. In general, high initial temperatures and humidity are employed to heat the ware with little loss of water, to produce the conditions outlined above for subsequent rapid and safe drying. The size and shape of ware which can be successfully dried for a given setting in this type of plant are strictly limited, however, and tunnel dryers can be considered only for large-scale continuous production of a single article. For smaller and variable outputs single chamber dryers operated batchwise, but on the same principles, can be used.

"Infra-Red" Drying

Some years ago great interest was shown in the possibilities of methods of heating and drying in which the necessary heat transfer was obtained largely by radiation, from sources at temperatures considerably higher than that of the air in convection methods. A study[8] in some detail of the principles, advantages and limitations of this process was made by R. Long and the present author in 1945, as well as an assessment of its possibilities for drying refractories.[9] There can be no doubt that, in principle, the infra-red method is quite unsuitable for drying the average run of refractory ware. In short, the main advantage

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of radiant heating is the high rates of heat transfer which can be obtained, but the usual consequence with almost all industrial materials (which are opaque to infra-red) is a high surface temperature and a steep temperature gradient. With clay ware in general the use of infra-red methods would tend to impose the conditions of steep temperature and moisture gradients which must be avoided, so that its successful use for drying sizeable ware such as standard bricks cannot be visualised. On the other hand, emphasis was placed at the time on the possibilities with thin articles such as sparking plug insulators, plates and saucers, thin holloware, etc.; with these there appeared to be considerable hope of achieving much higher drying rates without creating dangerous moisture-gradients. Since then several applications of the method to thin ware of this type have been advantageously put into production; trials have been made also on pottery, but the author is not *au fait* with the present position in that industry. It is to be hoped that some information will be forthcoming from the discussion on the present paper.

Some time ago members of the research staff of the author's Department at the University of Leeds had occasion to test out radiant heating methods on the drying of 4 in. dia. clay conduits, circular in section, with a wall thickness of $\frac{3}{4}$ in. Using an experimental infra-red dryer, it proved possible to dry the pipes satisfactorily in less than 1 hr., and there was no reason to suppose that faster rates could not have been achieved. The pipes were subsequently fired and glazed and showed no faults. No further tests have yet been carried out, but it would be of considerable interest,

(*continued on page* 157)

(Continued from CERAMICS, February, 1951)

SOME NOTES ON PLASTER

Plaster Part-Mould

ONE of the most frequently required tasks in an engineering plaster shop is the reproduction in plaster of an existing object. If precision is not necessary a flexible mould is usually quite acceptable, but if the finished cast is required to be made with a fair degree of accuracy the most suitable method is to make a plaster mould of the object.

If the original which it is intended to copy has undercuts which will not permit it to be withdrawn from the mould or if there are any considerable surfaces parallel or nearly parallel to the direction in which the mould opens, the friction will probably tear the engaging surfaces.

Therefore, prior to starting the job, the exact line on which the mould is to be open must be carefully faked up with plaster or other material. The original is then thoroughly cleaned of dirt and oil, and is given two or three coats of french polish if the surface is not perfectly smooth and resistant to water. The subject is supported so that the breakline is approximately horizontal, as shown in Fig. 5, and clay or plasticine is built up from the underside to the breakline, which must be very cleanly made. The exposed edge of clay is varnished and the surface of the clay and object is lubricated. Plaster is now mixed and built up over the exposed oiled face: when set, the half mould is taken off for examination, and the clay is removed from the covered side of the original.

In the second stage as shown in

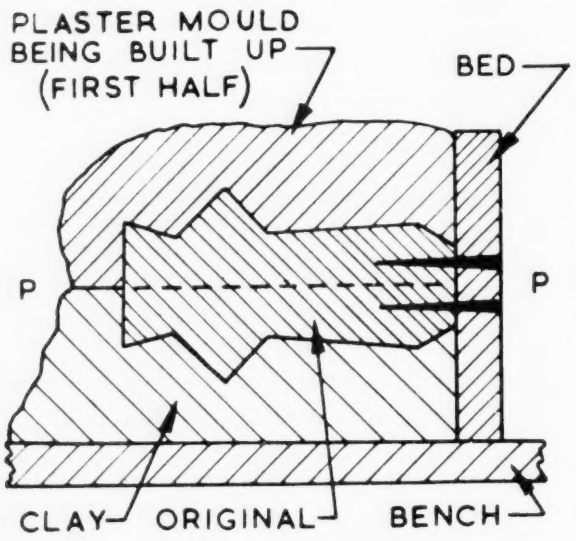

Fig. 5. Making a simple two-part mould — 1st. stage. The clay is built up to the parting line (P-P) and thickening plaster is formed over the exposed oiled surface of the original

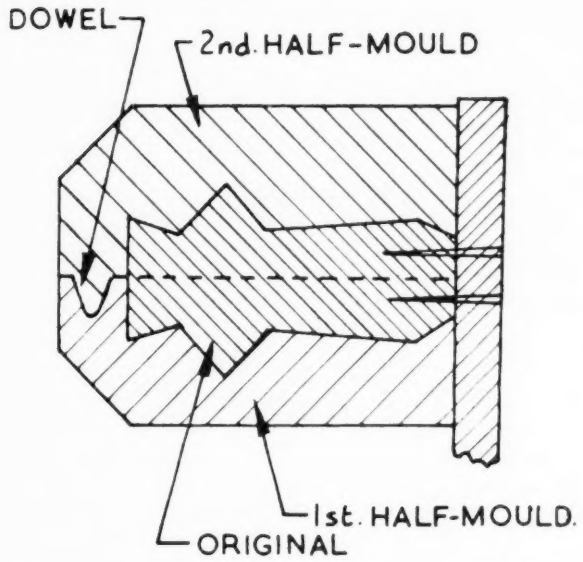

Fig. 6. Making a simple two-part mould — 2nd stage. The parting face of the first half has been drilled for dowels, varnished and oiled, and the second half-mould built up over it

Fig. 6, the half mould is drilled on the closing face to provide dowels which will ensure accurate closing of the mould when complete. The original is laid in the complete half of the mould, and the closing face is french polished and oiled, as is the exposed half of the original. The

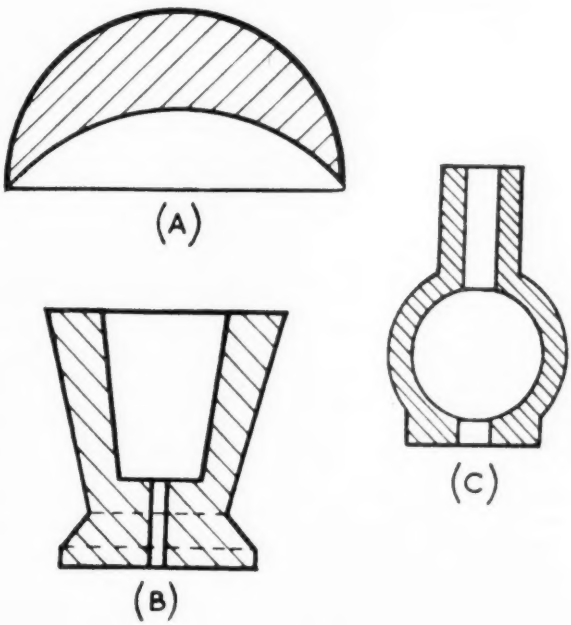

Fig. 7. Hollow plaster forms. Here are shown some difficult sections (circular in plan) which may be made by processes described in the paper. A is made with a plaster core and external strickle; B is made with external and internal strickles, the small hole being made by a paper tube used as a core; C is made with a wax core and outside strickle. The wax core is previously cast in a two-part internally strickled mould, or alternatively two half-cores of wax may be made in a one-part mould

second part of the mould is now built up in plaster and allowed to set off. Later the mould is opened and examined, and if satisfactory is touched up for surface and french polished inside; after oiling it may be used at once for casting.

In making the mould at least one opening is left for filling the mould, the necessary hole being formed by a stick of clay radiating out from the original. The position of such raisers as may be necessary is determined, bearing in mind the angle at which it is best to hold the mould during use, in order to prevent air being trapped in it. If the mould cannot be designed to open in two parts, three or more pieces may be used provided that they are all accurately registered together by means of dowels. Where three or more parts to the mould are necessary it is termed a "piece-mould," and is usually encased in a further covering of plaster which opens in two parts only.

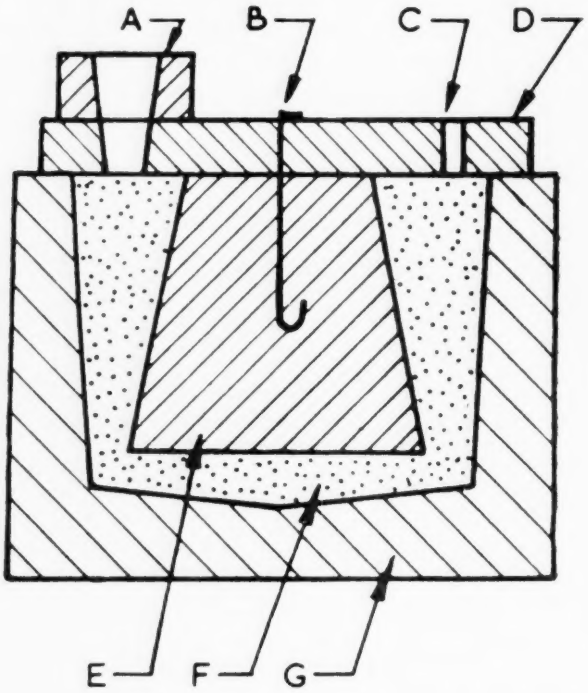

Fig. 8. Casting a hollow object with negative internal taper. The set-up shows the employment of a "waste-core" made of "killed" plaster, wax, papier mâché, clay, etc. A—header cup; B — suspension for core; C—vent; D—cope of mould; E—waste core; F—the cast; G—mould

Hollow Plaster Casts

It is often desirable to make a hollow plaster cast because such a cast is light in weight, dries out quicker, and generally is quicker and cheaper to make; typical examples are shown in Fig. 7. Hollow casts are also useful if two or more sections have to be screwed together as there are means of concealing screws and joins. There are several ways of making these casts, the best method being determined by the nature of the job

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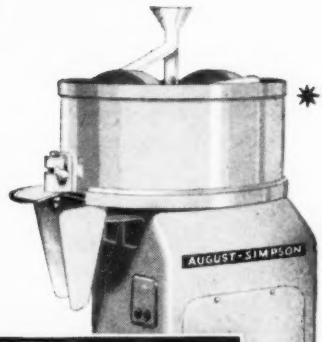

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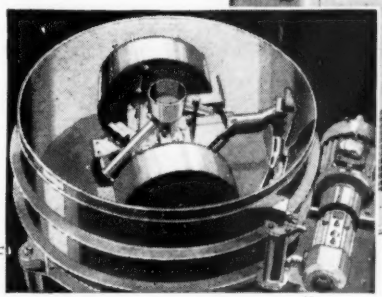

Inset picture shows the No. 2 size with mullers (adjustable for height from bottom of pan) and the plows which turn over the material and direct it in front of the mullers. The Hood (not shown) supplied as standard for all ceramic installations.

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making cheap hollow lead toys and ornaments. It consists basically of pouring metal into a heated mould, and then pouring it out again quickly: sufficient metal is chilled during the brief contact with the mould to leave a thin walled hollow casting. In plaster work, the same general principle is employed, except that to get the wall to sufficient thickness several internal layers must be formed, or the extra thickness obtained by building up with plaster in semi-plastic state.

Spun-Mould Method

If the interior shape is suitable, the mould may be placed on a turntable and revolved while the plaster is steadily poured in. The centrifugal force due to rotation will cause the semi-fluid plaster to spread out and cover the walls of the mould, but care must be taken to use the lowest speed that will produce this effect as otherwise the various constituents of the mix tend to separate out from each other.

Solid Core Method

Using this method a core is made of plaster or some other convenient material and removed after the casting is set. The core may either be of an extractable shape, or may be of clay or plasticine and picked out afterwards. Fig. 8 shows the general arrangement of the mould and core.

Wax Core Method

This is popular where a fair number of hollow casts from a single mould are required. The wax is either carved to the desired shape or cast in a separate core box. After pouring in the plaster with the wax core in position in the mould, the cast is removed from the mould and placed in an oven to melt out the wax. This has a certain similarity to the Lost Wax process with which it should not be confused.

Other methods include internal strickling, collapsible cores, and paper mâché cores which are picked out quite easily while wet.

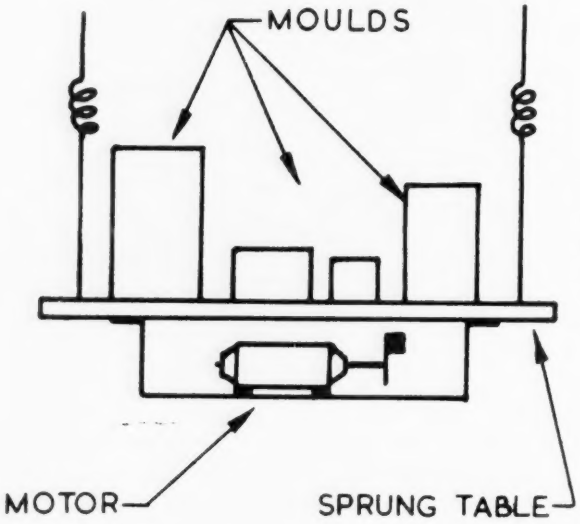

Fig. 9. Vibrating moulds. Showing spring - suspended table vibrated by an eccentrically - loaded electric motor

Vibrating Moulds

Much of the skill in plaster work is devoted to the avoidance of bubbles and trapped air in the moulds. Although good mould design and steady pouring at the

correct consistency should overcome most of the trouble, it is sometimes advantageous to vibrate the mould while pouring in order to encourage small bubbles to rise away from the faces of the mould. In production work where a number of moulds are filled together they are sometimes placed on a sprung table which is vibrated by light hammer blows: it is easy to arrange for this to be done mechanically as shown in Fig. 9, by mounting on the table a fractional h.p. motor having an eccentric weight on its shaft. Alternatively a cam action may be employed. Excessive vibration should be avoided when casting fairly thin sections in non-rigid moulds as the plaster is only lightly supported and tends to break if set off before the vibrations cease.

Lubricants

For easy extraction and good surface, moulds must be well lubricated. For very best work rape oil or cotton oil may be used, the rape oil being preferred as it does not stain the plaster or go tacky. For production work a cheaper mixture is used consisting of 1 oz. soft soap, ½ oz. sweet oil (olive or nut), and 1 pint of water: the ingredients are well boiled until emulsified, and then allowed to cool thoroughly before being applied to the mould surface with a small soft brush. After the mould has been lubricated it should be left for a few minutes to allow any excess oil to collect in the small hollows, from which it should be carefully removed with the soft brush. Wax moulds need lubrication, but care must be taken to use a lubricant in which the wax is insoluble. Soapy water is the best lubricant for the synthetic elastomer moulds.

The Plaster Shop

A well ventilated building is required for plaster working and plant to remove atmospheric dust is desirable. If the shop is to work with the foundry it is essential that it be well separated therefrom to keep the plaster shop free from fumes and dirt.

Plenty of wide, firm benches

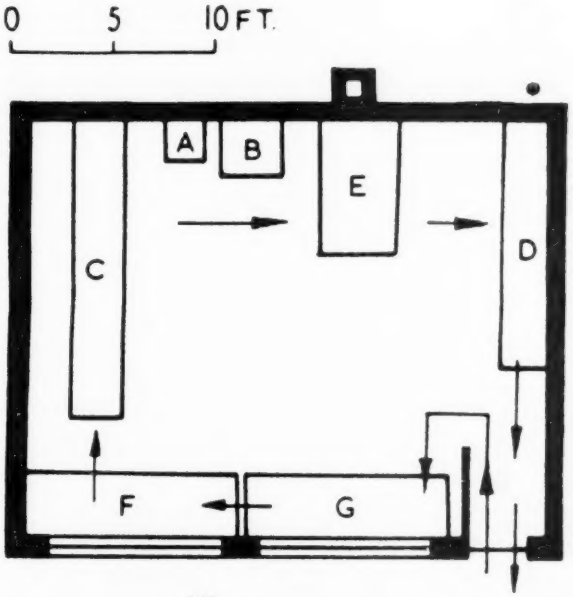

Fig. 10. Suitable layout for production workshop for engineering plaster work. A—sink with waste filter; B—washing cistern; C—workbench for casting and coarse work, with storage bins under; D — storage racks for finished work; E—hot air kiln for drying out plaster; F—workbench, mouldmaking and fine work; G — workbench, spindles, drills, chipping, etc. Note: the clear floor space at centre for setting out large jobs. Arrows show general workflow

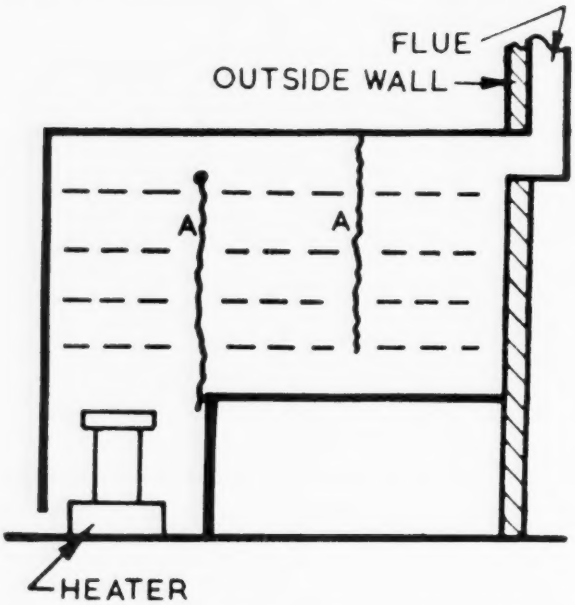

Fig. 11. Showing a simple kiln fired by an industrial paraffin burner. The canvas baffles A direct hot air through the racks. Both sides of the kiln are removable or consist of canvas sheets. A suitable size for general work would measure internally, 6 ft. long, 4 ft. wide, by about 3 ft. high. The internal racks should be removable to facilitate the drying of larger jobs

preferably hardwood faced, will be required, and the general arrangement should be roughly on the lines of the carpenters' shop (Fig. 10).

Large galvanized bins with lids will be required to keep the various materials clean and dry, and an adequate supply of clean water is essential. In order to prevent stoppage of drains all washing of utensils and tools should be done in tubs of water and not in sinks. The tubs should be emptied frequently, and their contents run through a fine filter before being passed to the drainage system.

A number of small power tools will prove an advantage, especially slow speed spindles, drills and grinders. Apart from hatchets, spatulæ and plaster knives, most of the tools are as used by the carpenter. If modelling is to be done, a modelling tripod will prove most useful, and the remainder of the equipment will comprise putty knives, modelling tools, files and rasps, and a few special tools which will be made from time to time as the need for them arises.

Adequate storage space is essential in the plaster shop, and a simple hot air kiln burning paraffin (Fig. 11) can also be erected in half a day.

Acknowledgment

It is hoped that the notes presented in this paper may help to make more complete the very scant published matter on the subject of plaster of paris in engineering. Very grateful acknowledgments are made to Mr. John Armstrong and to the directors of Arthur Saville and Co. Ltd., who have sponsored much of the experimental and development work which has led to the writing of this paper.

MR. H. DUDLEY

REPRESENTATIVES of many local pottery firms, together with Freemasons and friends, attended the funeral, at Penkhull Parish Church, of Mr. Harry Dudley, M.B.E., of Barnfields, Penkhull, who died recently at the age of 72.

Mr. Dudley was a former secretary and director of Mintons Ltd., Stoke.

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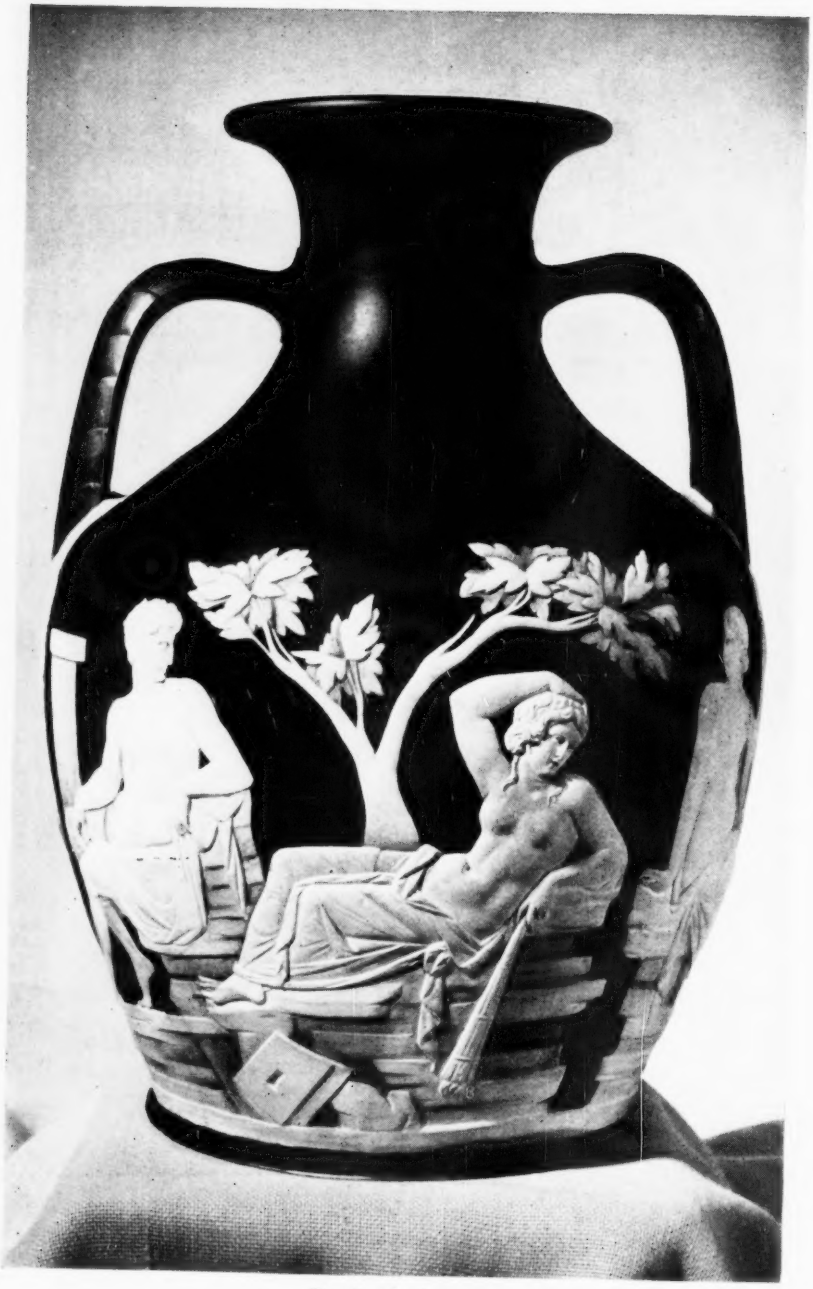


The Portland vase

An Historic Wedgwood Exhibition

A "CERAMICS" REPORT

OF the important ancillary exhibitions during the Festival of Britain, that opened on 9th May, 1951 by Alderman Denys Lowson, Lord Mayor of London, will rank as most important! It is the first occasion for more than 100 years since a comprehensive exhibition of "Wedgwood" has been shown to the London public, and it may be seen at the London showrooms of Josiah Wedgwood and Sons Ltd., 34 Wigmore Street, W.1.

In 1949, Wedgwoods held a similar exhibition of antique and contemporary ware in the Brooklyn Museum, New York City, and more than 100,000 people came along to see it. In effect, the present exhibition outlines the history of the production of six generations of the Wedgwood family beginning from Josiah Wedgwood, F.R.S., who started as a potter on his own account in 1759. Earlier documents also on show relating to the partnership of Wedgwood with Whieldon and early documents dealing with the history of the firm, provide interesting reading over something like ten generations since Gilbert Wedgwood (1588-1678) whom it was in 1612 married the heiress of a leading potter in Burslem and inherited his "pot bank." Altogether the exhibits outline a cross-section of the history of British pottery in the past 200 years.

One of the things often overlooked about Josiah Wedgwood, F.R.S. was that he was one of the first of the industrialists to introduce a specialisation in craftsmanship. This reflected the beginning of the "division of labour" in industry and enabled him to produce articles of remarkably fine detail and high quality largely because he was able to retain his workers year in and out, offering steady employment by building up stock during the slack periods. It is to be remembered that the common practice in those early days was seasonal employment resulting in a large labour turnover, loss of skill and dissatisfaction.

The firm have been very fortunate in a recent purchase of a private collection from Mr. Eustace Calland, which collection has never previously been seen by the public.

Broadly speaking the history of Josiah Wedgwood's activities can be sub-divided as follows:

1754-59. *Agate* wares — made from a mixture of coloured clays, and *Tortoiseshell* — made from cream coloured earthenware coated with glazes of different colours.

1759. *Green Glaze* and *Cauliflower* ware.

1759-65. Fine cream coloured earthenware, first called *Queen's Ware* when Wedgwood become potter to the Queen in 1765. This has been the staple product of the firm ever since. Of all the founder's achievements in design and technique it has had the most lasting and far-reaching effect on public taste and on the development of the British pottery industry.

1764-66. *Black Basalt* — a fine black vitreous stoneware.

1774. *Jasper*—a semi-porcelain or very fine stoneware in many colour combinations, of which blue and white is the best known. This was used for vases, teapots, jugs, medallions, cameos and plaques ornamented with classical reliefs, and for

(Left.) One of the six Black Basalt vases made to commemorate Wedgwoods' move to the new Etruria factory. (Right.) Two vases with covers, Jasper, white on black—"Chariot of Venus." Etruria 1790, and "Sacrifice to Ceres." Etruria, 1790

reproductions of antiques such as the Portland Vase. For his designs, Wedgwood enlisted the services of many well-known artists including Flaxman and Stubbs. Less well-known to the public but deserving of all honour as an artist and a craftsman was the chief works modeller, William Hackwood, some of whose portrait medallions are unrivalled.

Translucent *Bone China* or porcelain tableware—now one of the firm's principal productions—was first made by Josiah Wedgwood II, the founder's son, in 1812. It was discontinued in 1816 and re-introduced in 1878. Some of the early china is shown in conjunction with modern pieces.

A list of references to books and articles published on Wedgwood is annotated at the conclusion of this article.

The Portland Vase

Undoubtedly one of the outstanding triumphs of Josiah Wedgwood was his reproduction of the famous Portland Vase.

The original was made in glass in the 3rd century A.D. and was excavated from the tomb of Alexander Severus near Rome in the early 17th century. It then found its way into the library of the Barberini family and was regarded as one of the outstanding pieces in their collection. It was later purchased by Sir William Hamilton who sold it in 1785 to the Dowager Duchess of Portland. Her son heard that Wedgwood wished to make a copy and lent it to him for that purpose in 1786. After 4 years of experiment, Wedgwood succeeded in reproducing it and submitted his copy to Sir Joshua Reynolds, who declared it "to be a correct and faithful imitation both in the general effect and the most minute details of the part." It is uncertain how many copies were made by Wedgwood. There is, however, evidence that there were twenty-six subscribers to the first edition who paid prices between 20 and 30 guineas. Since that time a number of further copies have been made by the Wedgwood firm, and

there have been other less worthy imitations by other potters.

The one exhibited is one of the first issue. It was sold to Thomas Hope of Amsterdam in 1793 who appears in the original list of subscribers in Thomas Byerley's notebook.

The original vase is now in the British Museum. In 1848 it was unfortunately smashed by a madman, and it was restored with the aid of Wedgwood's copy.

Another striking contribution to the industry was Black Basalt which was a refinement of the Egyptian Black which other Staffordshire potters had been making in a somewhat cruder form.

Wedgwood moved from the Bell Works to his new Etruria factory on 13th June, 1769, and on that day six Black Basalt vases were made to commemorate the event. While his partner Bentley, turned the wheel, Josiah himself "threw" these pieces which were than painted with red classical figures in Etruscan style. Each was inscribed in Latin with the words "The arts of Etruria are re-born."

In 1754, Wedgwood entered into partnership with Thomas Whieldon of Fenton Low. Whieldon was a potter of considerable taste and with Wedgwood built up a good business in the marbled and agate wares, tortoiseshell and Egyption black. It was during this period that Wedgwood perfected his well-known Green Glaze ware which has been made and sold all over the world ever since. In 1759, Wedgwood started on his own account at the Ivy House Works, Burslem, rented from his uncles for £10 a year. Five years later, he moved to a somewhat larger works, the Brick House at Burslem, rented for £21 a year. It became known as the Bell Works, because the workmen were summoned by a bell instead of by a

Teapot, red ware, sprigged Imp and Arabesque pattern, Whieldon-Wedgwood 1757; Bowl, marbled, example of thin potting and well defined marbling. Whieldon-Wedgwood 1758; cream jug, green glaze, cabbage pattern, as made in Burslem in 1759. Etruria 1860; teapot, cauliflower, taken from Josiah Wedgwood's early pattern book, circa 1759. Etruria 1860; dish, combed brown and yellow slip decoration, serrated edge, made from local marls, Burslem 1760; beer mug, made from local red marls, strip handle, white slip decoration. Whieldon-Wedgwood 1756; cream jug, pear shape, marbled throughout, early example of side handle. Whieldon-Wedgwood 1756; teapot, marbled ware, pressed and turned, unglazed "slurry" finish inside, rolled handle. Whieldon-Wedgwood 1756

Two Black Basalt vases (left) thrown and turned, mask terminals, scale handles; (right) thrown and turned, applied husk festoons, scale horn handles, mask terminals—both No. 1 in Wedgwood's shape book of 1770. Marked "Wedgwood and Bentley." Etruria 1775

horn. This works he retained for his "useful" as distinct from "ornamental" ware until 1773.

It was in 1766 that Wedgwood bought for £3,000 the estate on which he built his new works, Etruria, and his own house which were completed in 1769. The examples shown in this section of the exhibition belong to the pre-Etruria period and many were found on the Whieldon-Wedgwood factory site.

Mention has already been made of Black Basalt which is a hard fine grain stone ware rich in hue, smooth in surface and capable of being polished on a lapidary sheel. It was described by Wedgwood himself as "A fine black porcelain having nearly the same properties as basaltes, resisting the attacks of acid, being a touchstone of copper, silver and gold and equal in hardness to agate or porphyry." He added "The black is sterling and will last for ever."

In the case of the variegated and marbled wares, there are two species —one which is coloured throughout and the other where the effect is on the surface only. A tortoiseshell effect was achieved by dusting metallic oxides on the surface of the vase—bronze for purple, copper for green, and so on. It was when the piece was fired that the mingling of the colours produced a variegated effect. A similar effect was also obtained by laying on lines and splashes of colour which were then combed or sponged together. Somewhat later the whole of the clay body was made to imitate natural stones such as agate. Clays of various colours were kneaded together to produce wares known under the names of "marble," "onyx," "porphyry," "granite," etc.

Jasper

However, undoubtedly one of the historic discoveries in the art came from Josiah Wedgwood's work on Jasper.

In 1774 after many experiments, Josiah Wedgwood recorded his discovery of "A white porcelain bisque of exquisite beauty and delicacy, possessing the general qualities of the 'Basaltes' together with that of receiving colours through its whole substance, in a manner which no other body, ancient or modern, has been known to do." This material was later named "Jasper."

Jasper is a dense white vitrified stoneware which is translucent in thin sections. It contains barium carbonate or sulphate and the finely

grained surface is never glazed. When Jasper is stained throughout the colour is called "solid." After 1775, however, colouring was sometimes obtained by dipping the white piece in a solution of liquid tinted Jasper, called "dip."

Wedgwood commissioned artists and modellers from many parts of the world to create designs for this new product. In a letter written to Sir William Hamilton on 24th June, 1786, Wedgwood referring to his vases, said ". . . one thing I persuade myself you will note. They have been the object of very much labour and time, every ornament and leaf being made in a separate mould, and then laid upon the vase with great care and accuracy, and afterwards wrought over again on the vase itself by an artist equal to the work, for from the beginning I determined to spare neither time nor expense in the modelling and finishing of my ornaments."

Cameos, portrait medallions, plaques, vases and other pieces are still made from Jasper, and there is a comprehensive display of these.

Another outstanding contribution to pottery was Wedgwoods' work on dry bodies.

Among the unglazed earthenwares which were produced extensively at the Etruria Works were Rosso Antico, Cane, Drab, Chocolate and Olive. All were made basically from local marls. To give them the right hue were added colouring oxides or "ochreous earths," but generally they were non-porous requiring no glaze.

Among the articles made from these materials included teapots, jugs, bulb pots for plants and flowers, ink stands, lamps and busts. Cane ware was also produced to imitate bamboo and piecrust, whilst these latter were extensively used in the early 19th century instead of genuine piecrust to save flour in times of scarcity.

In the "Life of George (Beau) Brummell" by Captain Jeffs (1844) it is said "The scarcity 2 years after Brummell's retirement, viz. in 1800, was so great that the consumption

Pair of vases, surface marbling, thrown and turned, snake handles, white Jasper plinths, traces of leaf gilding, applied acanthus leaves. Marked "Wedgwood and Bentley" Etruria 1772

of flour for pastry was prohibited in the Royal Household, rice being used instead. The distillers left off malting; hackney coach fares were raised 25 per cent. and Wedgwood made dishes to represent pie-crust."

Queen's Ware

Another Wedgwood contribution —perhaps his greatest—to the development of British pottery was his cream coloured table ware, generally known as Queen's Ware.

This is an ivory or cream coloured earthenware. In 1759 he recorded in the preface of his Experiment Book:

"This suite of Experiments was begun at Fenton Hall . . . in the Parish of Stoke upon Trent, about the beginning of the year 1759, in my partnership with Mr. Whieldon, for the improvement of our manufacture of earthenware, which at that time stood in great need of it, the demand for our goods decreasing daily, and the trade universally complained of as being bad and in a declining condition.

White stone ware was the principal article of our manufacture. But this had been made a long time and the prices were now reduced so low, that the potters could not afford to bestow much expense upon it, or to make so good in any respect as the ware would otherwise admit of—and with regard to Elegance of form, that was an object very little attended to.

The article next in consequence to Stoneware was an imitation of Tortoise-shell. But as no improvement had been made in this branch for several years, the country was grown weary of it; and though the price had been lowered from time to time, in order to increase the sale, the expedient did not answer, and something new, was wanted, to give a little spirit to the business.

I had already made an imitation of Agate; which was esteemed beautiful and a considerable improvement; but people were surfeited with wares of these variegated colours. These considerations induced me to try for some more solid improvement, as well in the *BODY* as the *GLAZES*, the *COLOURS*, and the *FORMS*, of the articles of our manufacture.

I saw the field was spacious, and the soil so good, as to promise an ample recompense to any one who should labour diligently in its cultivation."

For the first decade after he had started in business in his own account, he devoted his experiments to improving the quality and design of this cream coloured earthenware.

In 1765 he accepted an order to supply a tea service to Queen Charlotte, wife of George III. This and subsequent orders pleased her so much that she authorised him to call his cream coloured earthenware "Queen's Ware."

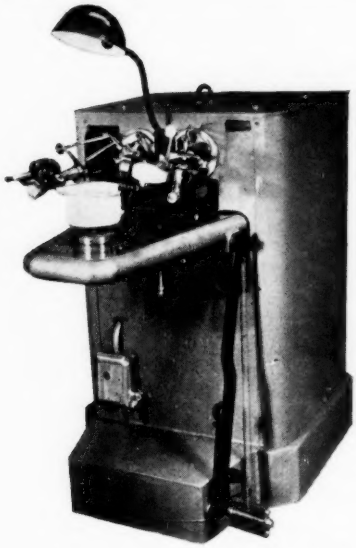
Of historic interest is Wedgwood's first pattern book which was begun in 1769 and carried through until 1814.

It shows the borders used for the decoration of the early Queen's and later the Bone China made during the years 1812-1816. In 1769 or 1770, Wedgwood's partner, Thomas Bentley, established a workshop in Cheyne Row, Chelsea, London, and supervised the artists. The Wedgwood's showrooms at that time were at the corner of Newport Street and St Martin's Lane for Newport Street was a great resort in those days for artists and literary men such as Sir Joshua Reynolds, George Romney, Ward and Humphrey. The pattern book shows the changing styles of pottery decoration in the late 18th and 19th centuries. The first patterns are in the restrained classical style whilst later, as trade developed with the Orient, Chinese motifs became fashionable.

Wedgwood for China and Russia

In 1793, Lord McCartney, British Ambassador to the Imperial Court of China, presented gifts of Western manufacture to the Emperor. The Emperor was most pleased with the Wedgwood wares and had them copied at the Imperial Porcelain factory.

In 1774, the Empress Catherine of Russia commissioned Wedgwood to make a dinner and dessert service for the Royal Palace. This was in many ways Josiah's greatest undertaking in Queen's Ware for the set consisted of 952 pieces, each



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With his new tableware, Josiah Wedgwood laid the foundation of his fame and success. The body and glaze, the material, the potting and above all the shapes, many of which have outlasted the changes of fashion for nearly two centuries, commanded the admiration and custom of the civilised world. These wares had a profound and lasting influence on technique and design in the whole of the British pottery industry. Many of these shapes appeared as early as 1768. He called them his "useful wares." In spite of their fine quality he regarded them as utility pieces for general use. They were never given special names to attract attention, but were simply referred to by their catalogue reference numbers, such as "146 teapot" or "129 coffee pot" which names survive today.

In all questions of the design of tableware Wedgwood sought the advice of his wife and Mrs. Bentley, for in a letter to his partner, Thomas Bentley, he says:

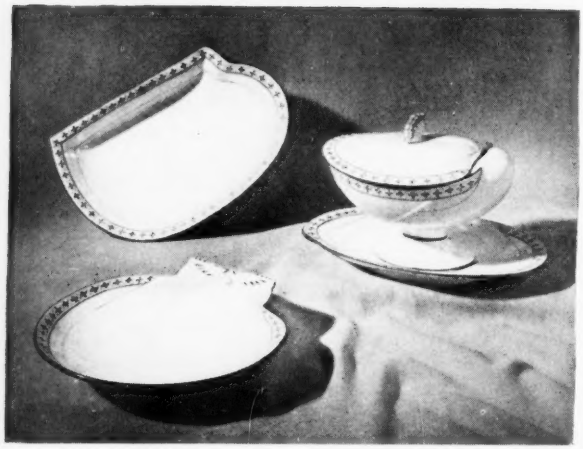
"Sally is my chief helpmate in these as well as other things, and that she may not be hurried by having too many irons in the fire, as the phrase is, I have ordered the spinning wheel into the lumber room."

In another letter, he says:

"Mrs. Wedgwood has tried our new teapots, of which we send you one, and gives them her sanction, as the best and most pleasantest in the hand she has ever used. I wish Mrs. Bentley would be so good to use this pot and favour me with her corrections that we may bring them out as perfect as may be."

or again, he writes:

"I speak from experience in female taste, without which I should have made but a poor figure among the pots, not one of which of any



Dessert service, "Nautilus" shape, Queen's ware, consisting of one centre and stand, two sauce tureens and stands and nine compotiers. Decorated with No. 384 design from Josiah Wedgwood's pattern book of 1770. Marked "Wedgwood" Etruria 1798

consequence is finished without the approbation of my Sally."

It was in 1768 that china clay and china stone were discovered in Cornwall by Cookworthy who took out a patent for their use in the production of china and later sold his patent rights to Richard Champion.

Champion was one of the chief supporters in Bristol of Edmund Burke, Member of Parliament for that city and in 1775 he conceived the idea of having a Bill passed through Parliament to extend the patent for a further 7 years. Previously, however, china clay and stone had been proved to be of value not only in the making of china, but also as a constituent of the cream coloured earthenware made in Staffordshire. These materials had been transported thither and used by Wedgwood and others for this purpose. For this reason an extension of Cookworthy's original patent giving Champion a monopoly for a further 7 years of the sole right to use china clay and china stone for the making of earthenware as well as china was naturally resisted by the Staffordshire potters.

In this successful opposition

Early morning set, cane ware, four pieces consisting of a teapot, sugar, cup and saucer and tray, painted in red and blue encaustic colours, bamboo motif. Marked "Wedgwood" Etruria 1792

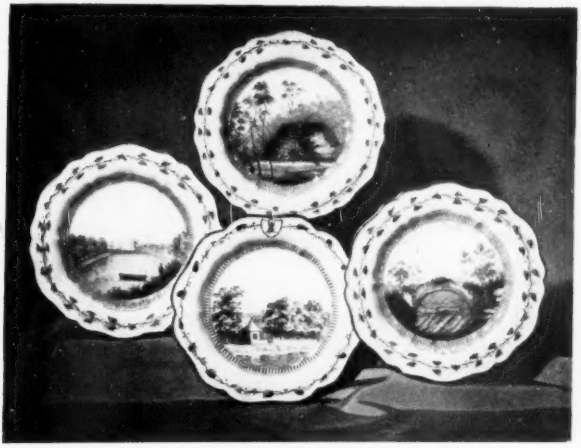
Wedgwood, always strongly opposed to monopoly, played a leading part. His action has been criticised by those who thought they saw in Champion a struggling inventor resisting unfair pressure from selfish capitalists. Yet it is elsewhere claimed that Champion was not an inventor, he was merely attempting to increase the value of an investment in a patent which he had purchased at a modest figure. As William Burton writes in his "History of Porcelain," "It certainly seems that the fullest justice was done when Champion was allowed an extension of the patent for the use of china clay and china stone *in porcelain*, the only substance ever produced by Cookworthy or Champion."

Wedgwood himself never undertook the manufacture of fine china and it was first made by the firm in the days of his son, Josiah II, from 1812-1816. For some reason or other it was not revived again until 1878, in the days of the founder's grandson.

Those going along to this exhibition in London as well as being able to study the contemporary development of 200 years of British pottery will also be able to see some historic documents which throw a light on the Wedgwood family and show the manner in which commerce was carried on in those days when Britain was aspiring to greatness, when wars and rumours of wars, as we know them today, were something of the great unknown.

Even so, those in love with pottery and happening to be in London will call in at 38 Wigmore Street, to see woven before their eyes patterns of the industrial revolution revealed in pottery—which is after all, one of the most fascinating of British enterprises.

This article is published with full acknowledgment to "Early Wedgwood Pottery," the title of the catalogue introducing the exhibition.



Plates made in connection with the Catherine Service commissioned by Catherine of Russia in 1774

BOOKS AND ARTICLES ON WEDGWOOD

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"Josiah Wedgwood" by A. H. Church. Publishers—Seeley and Co., 1894. New edition 1903.

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Bone china, hand painted in colours, various scenes Etruria 1815

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MR. G. SENIOR

MR. G. SENIOR, joint managing director of Richard Sutcliffe Ltd., Universal Works, Horbury, has announced his retirement. To mark the occasion the presentation of a solid silver cigarette box, suitably inscribed, was made to Mr. Senior by Mr. G. Still on the 20th April, 1951, in the works canteen. Mr. Still is the longest serving member of the works staff.

After a brief introduction by Mr. A. Hill, chairman of the works committee, Mr. T. Milner, the works director, gave a brief outline of Mr. Senior's association with the company. Mr. Still then presented the cigarette box, and Mr. Senior replied thanking all those concerned with the presentation. The proceedings continued with a few remarks by Mr. R. J. Sutcliffe, the chairman of the company, after which bouquets were presented to Mrs. Senior and to Mrs. Sutcliffe.

Mr. Senior joined the company in 1912.

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and has seen the small workshop as it was at that time grow into a modern factory. During that time he has won the esteem and affection of all those who have come into contact with him, either in his employ or in business generally.

Mr. Senior has been a member of the Horbury U.D.C. for the past 15 years, and is a past chairman. For many years he served as chairman of the Parks and Cemeteries Committee, for the last three years he has been chairman of the General Works Committee, and he is president of Horbury Band, president of the Horbury Branch of the British Legion, president of the Horbury and District Gardens and Allotments Society, a past president and a present vice-president of the Horbury, Ossett and District Chrysanthemum Society, a member of Horbury Old Folks' Treat Committee, president of St. Peter's parent and teachers Association, president of Horbury Juniors Football Club, chairman of the Gaskell Division Education Committee, and divisional commander of the Wakefield Division of the West Riding Special Constabulary.

DRYING OF REFRACTORY MATERIALS—(*continued from page* 137).

both academic and practical, to study the moisture distribution in materials dried under such conditions and to determine the maximum thickness at which clay ware could be rapidly dried.

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BRITISH POTTERY MANAGERS' AND OFFICIALS' ASSOCIATION

LONGTON AND FENTON BRANCH

AT the monthly branch meeting of the above, held on the 21st February, 1951, the President-elect of the Association, Mr. H. Hulse, Birlec Ltd. (who was introduced by the Chairman, Mr. H. Degg), gave a talk on "Short Cycle Firing."

The overall length of the oven under discussion was 70 ft., while other particulars were as follows:

Door to door 60 ft. Pre-heat and loading 17 ft. 6 in. approximately. Heating chamber 18 ft. 6 in. Cooling and unloading 31 ft. On a 6 hour cycle = 2 in. per minute. The time in heating chamber is 111 minutes. The capacity in dozens at 6 hour cycles: teaware (approximately) 5,600 dozen per 7 day week. Average consumption 2,400 units per day at 0·3d. per unit. Additional coal factor £6 8s. 0d. per day, or £44 16s. 0d. per week. The cost per day for electricity is (approximately) 1s. 9d. and the cost per c. ft. 2·13d. (5,040 c. ft. per week of 7 days). The cost per week at 6 hour cycle of 5,600 dozen would be £160, and the cost per dozen 6·85d. (approximately).

Weight on Belt

The present "fill" is 7½ lb. per sq. ft. consisting of eight cranks of 5 in. plates, or saucers, containing sixty-four pieces, plus sixteen bats containing sixty cups.

The approximate per centage weight of furniture being 41 per cent. and of ware 59 per cent.

Maintenance of the belt was a very important factor and the life of the belt approximately 12 months. Experience lead to the use of Duplex and flat spiral belt.

Mr. Hulse illustrated the firebox and heating zones, and also exhibited several samples of leadless and low soluble glazes to illustrate further some of the points made during the talk.

At the conclusion of a most interesting and informative talk, questions were literally fired at Mr. Hulse, who replied to all with confidence.

BOOTHS & COLCLOUGHS LTD., REPRESENTED AT THE FESTIVAL OF BRITAIN

BOOTHS AND COLCLOUGHS LTD., are taking a very active part in the Festival of Britain, being represented both at the South Bank Exhibition and also at the Festival Gardens, Battersea. The Booths' patterns which are being displayed at the South Bank site are as follows: Dovedale, Real Old Willow, Lowestoft Rose, Flowerpiece, Green Dragon, Fresian, special hotel design and plain white Stratford.

For the fortnight, 17th to 29th September, Booths and Colcloughs are providing a team of demonstrators who will show visitors to the South Bank Exhibition the methods used in the decoration of pottery. This team of demonstrators will include women under- and on-glaze painters, lithographers and engravers. The first week's demonstration will be devoted entirely to Booths' fine earthenware, and the second week to Colcloughs' bone china.

Booths and Colcloughs Ltd., have secured sole rights in the sale of all earthenware and bone china at the Festival Gardens, and both Booths' and Colcloughs' ware will be on sale to the public at one of the Garden kiosks, the staff for which is being provided by Selfridges Ltd. Owing to limited space in the kiosk, orders taken here will be packed and dispatched by Selfridges from their Oxford Street address.

THE DRYING OF HEAVY CLAY ARTICLES*

by

H. H. MACEY
M.Sc., A.R.C.S., D.I.C., F.Inst.P., M.Inst.F.†

THE fundamental considerations in drying in the heavy clay industry are the possibility of cracking, which imposes a slow drying schedule, and the very large quantities of water to be evaporated, which necessitate the use of the cheapest form of heat. A moderately small works with a single continuous kiln will have an output of the order of 120,000 bricks per week in the drying of which, prior to burning, some 60 tons of water will be removed, while it is not uncommon to meet dryers dealing with a ton of water an hour. With such quantities, and remembering that the brick is the cheapest manufactured article per ton weight, it is obvious that the cost of fuel is of primary importance. Thus, although it may have been found, for example, that heavy clay articles can be dried very rapidly by radiant heat, the cost of gas or electricity is so high as to rule this method out on economic grounds, and clay dryers operate on steam or hot air (or both), produced either as waste products of other processes or by using coal or coke as the primary fuel.

Causes of Cracking

Cracking is consequent upon the shrinkage which is associated with the removal of water from plastic clay, and occurs when the drying is too rapid or uneven. As is well known, the drying of any substance may be divided into two periods, one of constant rate of evaporation under constant conditions of temperature and humidity; and one, at lower moisture contents, of falling rate of evaporation under the same conditions. In the case of clay, in contrast with most other materials, it is the earlier (constant-rate) period which is of primary practical importance, when the surface of the article is constantly wet and the change in volume of the clay is equal to the volume of water lost. Removal of water causes a reduction of moisture content and a shrinkage in the surface layers relative to the interior.

Plastic Deformation and/or Distortion

This occurs at every rate of drying no matter how slow, since it is this differential moisture content which causes the flow of water from the interior to the surface, and when the rate of drying is high these differences in shrinkage become sufficient to cause cracking. No general rules of greatest safe rates can be laid down, since the differences in moisture content produced in the same size of article made of different clays vary widely with the nature of the clay, as does its ability to withstand stress.

In addition to this comparatively simple and straightforward cracking

* This paper has been contributed, at the invitation of The Institute of Fuel, to a symposium under the general heading "A Study of Drying," which is being conducted during the 1950-51 Session.

† Western Counties Brick Co. Ltd., Exeter.

plastic deformation and/or distortion can occur during drying. These effects are perhaps more serious and of greater practical importance as they are more difficult to trace. When a flat article is dried, it is impossible to avoid more rapid drying near the edges than in the centre. Those edges shrink the more rapidly and are in tension. Over the whole period of drying they shrink less in the plane of the article (and correspondingly more in the thickness, so that the total volumetric shrinkage remains the same) than the central areas, and when the article is finally dry the outer portions are, in effect, too large for the centre, which cracks. The form of crack is quite typical, open when dry, running across the centre and not reaching the edges. This effect is considerably complicated by the fact that it may not appear in the drying, but only in the subsequent burning. In some instances it may not even appear then, but only after the article has stood or been in use for considerable periods of time. Distortion can occur in a similar manner or through the "memory" effect. A clay article which has been made flat (as is a plain roofing tile) and then bent (as the tile is to produce camber) will tend to straighten during drying.

Control of Drying Process

It might be thought that these considerations and the need for care showed circumstances in which control, and particularly instrumental control, of drying conditions would be very valuable and widely adopted. This is not the case, however, automatic control being more or less limited to a few instances of thermostats on mechanical stokers. To be more popular, control of humidity requires a reliable instrument which will operate successfully at the high temperatures and in the dusty atmospheres encountered in practice. A further important reason why controls are not more widely adopted is that the incidence of cracking is by no means sudden. On many works a few articles are normally lost in the drying, and as the severity of that drying is increased, so is the proportion cracked, but by no means suddenly. Even with comparatively violent drying a large number will probably remain sound. This wide variation between behaviour in mass-produced articles is merely one of the illogical characteristics of clay, but it does mean that a definite point of control of conditions is not easy to define and that the value of automatic control is correspondingly reduced.

Types of Dryers

Apart from open-air racks where bricks take their chance with the weather and which are more practicable only on the smaller yards of the southern counties, dryers consist of three main types—the hot floor, the tunnel and the chamber or corridor. There are, of course many variations of each, some logical and some not so logical, but in our present compass we can do no more than attempt an outline of their salient features.

The Hot-floor Dryer

The hot-floor dryer, as the name implies, consists of a floor, usually of concrete, heated below by direct fires in flues or by steam, and with a roof over. It lends itself to slow drying, to the manufacturer of articles requiring individual attention and to the drying of miscellaneous shapes and sizes at the same time; for each floor has its idiosyncrasies—hotter parts which are used for the smaller, and cooler portions for the larger pieces. Evaporation takes place by convection, the rising of air heated by contact with the floor around the clay shape, and by direct conduction from the floor through the clay. Drying is therefore uneven, the bottom of the

piece drying first, and for this reason the safe rates of drying on a hot floor are less than in other types of dryer using convection alone. To assist in this respect, direct contact with the floor is sometimes avoided by the employment of low wooden stillages or stands.

Low Thermal Efficiency

Once the air has been in contact with the floor, has been heated and has risen over the article, it escapes through the roof or walls. Furthermore, temperatures and humidities must be kept quite low as operatives work on the floor space, and conditions must be such as not to cause discomfort. Because this type of dryer relies upon single air/clay contact at low temperature and humidity, its thermal efficiency is low and rarely exceeds 10-15 per cent. on the basis of heat in solid fuel, being frequently lower. One consequence of this is that the waste steam on works using steam for power is insufficient for drying, and live steam has to be used at night at some considerable expense.

Not Easy to Apply

A further weakness is that waste heat in the form of hot air from kilns is not easy to apply effectively. It is difficult to get the air down amongst the goods without producing locally such high velocities and rates of drying as will cause cracking. Nevertheless, in spite of these drawbacks, the hot floor is still used quite extensively to meet, as already indicated, the peculiar requirements of the classes of goods being made. Plain tiles, for example, when stacked on one another in a solid "bung" or "burn" or against one another, are amongst the most difficult of things to dry, as all evaporation must take place from the edges. Such a pile of individual pieces does not have such strength to resist cracking as would a solid mass of the same size. They are normally dried very slowly on a hot floor. Singly, the rate of drying could be much greater, but the space required would not be so much less and the plant required would be much more complicated and expensive, while there is always the considerable risk that tiles dried singly would not retain their curvature and so could not be nested together for burning.

Similar considerations of accepting low thermal efficiency for practical reasons apply to dryers consisting of wooden racks heated by steam pipes, such as are used for hand-made tiles.

The Tunnel Dryer

The tunnel dryer comprises a series of tunnels through which the articles, usually bricks, pass on cars, being dried either by steam pipes below the car tracks or by hot air. In the latter case the direction of air flow is most commonly counter to that of the bricks, so that drying commences in a humid atmosphere at relatively low temperature and is finished in the hot dry air just entering the dryer. This method has the immediate advantage of giving repeated contact between air and bricks, but to ensure this, care must be taken to see that the setting on the cars fits closely to the interior of the tunnel. Drying at the lower levels on the cars is greatly assisted, and a more suitable gradient in drying conditions through the length of the tunnel obtained, by admitting the hot air at various points along the length of the tunnel beneath the cars. In steam-heated tunnels, repeated contact between the air and the goods is obtained by natural convection, the air heated by the steam pipes rising through the setting repeatedly as it makes its way from one end of the tunnel to the other.

The tunnel dryer lends itself particularly to the regular production of a standard article, for once adjusted it will operate indefinitely provided the input of wet goods and of hot

air remain steady and constant. The temperature and humidity of the air leaving the dryer and the initial rate of drying of fresh goods obviously depend on the balance between the rate of throughput of those goods and the hot-air supply. Over week-ends, when manufacture is stopped, this balance is upset and the initial rate of drying on Monday mornings is high. A margin of safety in drying rate is necessary, and this is one reason why the tunnel dryer is more suited to the simpler shapes.

Specific Heat Consumption

The specific heat consumption, i.e. the heat required to evaporate and remove 1 lb. of water, may be regarded as consisting of two parts, the latent heat of evaporation and the sensible heat used to raise the temperature of the drying air from atmospheric to that at which it is exhausted from the dryer. At higher operating temperatures the weight of air required to carry away 1 lb. of water decreases rapidly, and although its rise in temperature from atmospheric to exhaust is larger, the sensible heat absorbed by it (and, therefore, the specific heat consumption) are reduced. Tunnel dryers normally operate at such higher temperatures and for this reason thermal efficiencies much greater than those of the hot floor can be realised. Theoretically, operating temperatures could be raised indefinitely with a corresponding increase in efficiency, but this is limited by various factors. One is the higher losses through the walls, roof, etc., of the structure. A second is the increased difficulty of obtaining uniform drying when the actual quantity of air is severely limited, as it must be to realise the higher efficiencies.

Condensation

The third, possibly of greatest practical importance, is condensation. The cold bricks entering the dryer encounter the air in condition just prior to its exhaust, and, the bricks being normally below the dew point, some condensation occurs on them. If this be too heavy, this water is absorbed by the clay and on subsequent drying a network of fine cracks appears on the surface of the brick, spoiling its appearance. The effect depends on the nature of the clay and, once again, no definite rules can be laid down; but, all things considered, it appears that the maximum conditions of the exhaust air are generally represented by a wet-bulb temperature of 86°-95° F. This corresponds to an inlet temperature of the order of 257° F. Under these operating conditions the thermal efficiency of a tunnel dryer, based on heat in hot air, can be over 50 per cent.; while, based on heat in solid fuel, a figure of 33 per cent. may be considered reasonably good.

The Chamber Dryer

In the tunnel dryer the goods are moved progressively through the tunnel as the drying proceeds. In the chamber dryer they remain stationary, the dryer being filled and emptied at the appropriate stages of the cycle. This distinction, although a little obvious, is the essential one, as a chamber dryer is frequently constructed in the form of long tunnels or corridors which are filled at one end and emptied from the other.

The most common form of chamber dryer is that which employs the system of handling associated with the name of Keller. Here the bricks are placed on pallets as they come from the machine and a type of fork-lift truck on rails is used to pick up vertical sets of such pallets and to take them into the long narrow corridors where they are put down with the ends of the pallets resting on a series of ledges built into the opposing walls. The Keller dryer proper employs a battery of steam pipes, frequently gilled, in the bottom of the chamber below the rails as the means of heating, but

many designs have been put forward using the same method of handling and hot air as the drying medium. Here one difficulty is to prevent the hot air from rising to the top of the corridor, drying some bricks and leaving others wet. A second is that air at the initially high temperatures required for thermal efficiency (*circa* 257° F.) will crack fresh goods if admitted to them, and this has led to designs wherein two or more chambers are connected in series by means of cross flues. The need for repeated contact between air and clay, automatic in the tunnel, is also a consideration, and not easy to ensure in the chamber type. Thus, although some chamber dryers are operated on hot air, steam is simpler and more common.

Human Element

With a system in which a chamber can be filled with fresh goods before the steam heat is turned on, the complication of condensation does not occur. During the constant-rate period drying in a chamber can be carried out with wet-bulb temperatures of the order of 104°-113° F., and with very high thermal efficiency. The weakness of the chamber system is, however, that it relies too much on human nature and requires too much regular attention to the adjustment of dampers and the turning off and on of steam valves. At the end of the drying operation, chambers have to be cooled before they can be entered and emptied. All too frequently the operator opens the doors but omits to turn off the steam, when the rate of heat dissipation is high—as it is from an empty chamber with the steam on. Furthermore, the rate of air flow through each chamber depends on the chimney effect of the difference in temperature between inside and outside. When the bricks reach the stage of cessation of shrinkage and pass into the falling-rate period, the lower rate of evaporation gives a higher exhaust temperature and a

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higher draught, which in turn results in a greater air flow and rate of transfer of heat from the steam pipes. Strictly speaking, under these conditions dampers require almost constant attention, and, failing this, the thermal efficiency decreases considerably during this stage of drying. For these reasons the overall efficiencies of this type of dryer are in practice not very good—about 20 or 25 per cent. on the basis of heat in solid fuel.

Humidity Drying

On the other hand, the chamber dryer is perhaps to be preferred to the tunnel for the drying of articles which have a tendency to crack. Each chamber is or can be made a separate entity and there is no such variation in the initial rate of drying after the week-end as occurs in the tunnel dryer. In this respect, also, it is possible to adopt in the chamber (but not in the tunnel) the practice commonly but somewhat unfortunately known as "humidity" drying. This consists in turning on the steam to a freshly filled chamber with all dampers closed so that the ware is heated in an atmosphere saturated by moisture evaporating from it, and may be beneficial for two reasons. When a clay article is heated in a saturated atmosphere without drying, the temperature difference between the surface layers and the interior causes a movement of water to the interior and moisture content differences of the same kind as are produced by drying. If heating and drying occur at the same time, stresses and risk of cracking are increased, but by severely restricting the drying in the early stages it is possible to prevent all but stresses due to temperature differences, and even these disappear on soaking. Secondly, clay articles when made invariably possess some differences of moisture content between one part and another which do not enhance their ability to withstand drying strains, and which are alleviated by a period of rest. It is possible with some clays by this preheating/resting period to dry so rapidly afterwards as actually to show an overall saving of time. On the other hand, other clays do not respond at all to "humidity drying."

The Mechanism of Cracking

Extraordinary differences exist between the various conglomerations of minerals which are mined and worked under the generic name "clay." Some bricks may readily be dried quite unevenly in less than 24 hr.; others show considerable losses with a drying time of a week. It is here that there exists a large but recognisably extremely difficult field for investigation, as it is only by understanding why cracking occurs that real progress can be made in avoiding it. The mechanism whereby the moisture content gradients are set up in the clay during drying is known, and it is possible to calculate these gradients in any given clay at a given rate of drying subject to the limitations of heat-flow mathematics, with which the problem is analogous. Supposing that this mathematics were available, even for the simplest case of a brick drying freely from five of its six surfaces, the real problem would still remain, that of translating the moisture content gradients, which are strain, into stress in a plastic material which does not obey Hooke's law. This is the field of rheology, where clay does not lend itself to experimentation owing to the impossibility of ever reproducing results on identical samples. Nevertheless, some fundamental reasons must exist why one brick can be dried ten times faster than another, and if these were known it might be possible more accurately to control the drying process, to eliminate, maybe, some of the less efficient methods which now must be suffered for the sake of safety, and so to realise a general improvement throughout the industry.

The British Ceramic Society

Refractory Materials Section

THE Spring Meeting of the Refractory Materials Section (chairman Mr. W. Boyd Mitchell, M.B.E.) of the British Ceramic Society will be held in Sheffield on the 6th and 7th June, 1951.

The morning technical sessions will take place in the Royal Victoria Station Hotel, Sheffield. The detailed programme is as follows:

Wednesday, 6th June, 1951
Business Session (Council only)

9.30 a.m. Meeting of the Section Council.

Technical Session

10.00 a.m. "Low Alumina Silica Bricks for Open-Hearth Furnace Roofs."
This paper will be presented and discussed in the following Sections:
"Raw Materials"
Dr. W. Davies (The United Steel Co.'s Ltd.)
"Manufacture"
T. R. Lynam, A. Nicholson, P. F. Young (Oughtibridge Silica Firebrick Co. Ltd.)
"Properties and Performance"
Mr. J. Mackenzie (The United Steel Co.'s Ltd.)
"General Summary and Conclusions"
Dr. J. H. Chesters (The United Steel Co.'s Ltd.)

Works Visits

12.30 p.m. Cadeby Party depart for the Cadeby Works of The Steetley Co. Ltd.
1.15 p.m. Arrive at the Cadeby Works for lunch, followed by inspection of plant.
1.00 p.m. Fireclay Party, lunch at the Royal Victoria Station Hotel.
2.00 p.m. Depart for J. J. Dyson Ltd., followed by tour of inspection.

Evening Picnic

7.00 p.m. Picnic buses and cars depart from the Royal Victoria Station Hotel for the "Dukeries."

Thursday, 7th June, 1951
Business Session at the Royal Victoria Hotel

9.30 a.m. General Business Meeting.

Technical Session

10.00 a.m. "Trials of Refractories in Steel Plants."
Mr. J. Pluck (Steel, Peach and Tozer).
11.00 a.m. "Foreign Impressions."
A discussion on the refractory manufacturing and using industries abroad, introduced by Dr. J. H. Chesters supported by two users and two manufacturers of refractory materials. (The introductions and discussions on this subject will not be published.)

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1.00 p.m. Lunch at The Royal Victoria Station Hotel.

Works Visits

2.30 p.m. Visit to Steel, Peach and Tozer, Templeboro' Works, near Sheffield.

Dr. J. H. Chesters and Mr. J. Mackenzie, The United Steel Companies Ltd., Research and Development Department, Swinden House, Moorgate, Rotherham, Yorkshire, are acting as Local Secretaries. All enquiries relating to hotel accommodation, transport arrangements and other details of the Meeting should therefore be addressed directly to them.

Building Materials Section

The next meeting of the Society's Building Materials Section (chairman Mr. M. S. Whitehouse, M.B.E.) will be held at the Midland Hotel, Manchester, on the 11th July, 1951, where a number of papers will be read and discussed. Permission has been given to visit one of the works of J. and A. Jackson Ltd.

A detailed programme will be circulated later.

Information from F. H. Clews, Hon. Section Secretary, The Mellor Laboratories, Hanley, Stoke-on-Trent.

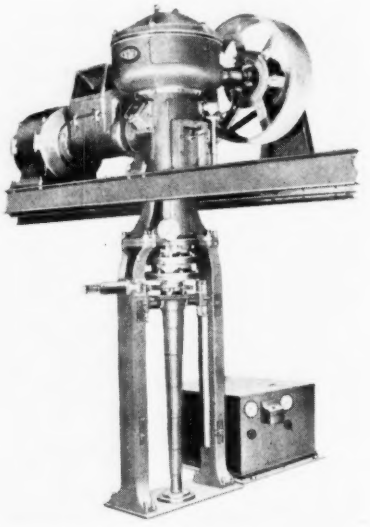
A NEW PIPE-MAKING MACHINE

BRADLEY AND CRAVEN LTD., showed on their stand at the B.I.F. Castle Bromwich a new type of hydraulically operated de-airing sanitary pipe machine incorporating the Hepworth automatic hydraulic control. This machine is fully automatic and is provided with a constant feed and is being offered in five sizes ranging from 8½ in. to 18 in. diameter barrels.

It is claimed that the output of these machines has increased by 100 per cent. over the previous types and the output per man shift has been found to increase by 200 per cent. The machine may be operated either manually or automatically, in the latter case continuing to make pipes once the initial cycle has been started. An important feature due to ingenious design is that the automatic unit never gets out of phase but automatically adjusts itself to the extrusion rate of the machine.

It is further claimed that once the correct fringe length has been decided upon this too remains constant no matter how the extrusion rate may vary. Additionally the design of the compound ram is such that the socket die is controlled hydraulically and can readily be set to give any return rate up to 2 ft. per sec. This return rate remains constant till immediately before the dies are closed when the travel is instantaneously decelerated to a closing rate of 1 in. per sec. Thus there is no hammering of the die faces, the closing being progressive and smooth, giving longer die life.

The machine is of totally enclosed construction, all moving parts operating under oil pressure and there being no possibility of clay particles getting on to working surfaces. Under arduous test conditions no measurable wear has been found in the production of 1 million pipes at an average rate of 750 pipes per hr. These machines are being made in collaboration with the Hepworth Iron Co. Ltd., whose design for the hydraulic control are the subject of numerous patents.



New pipe-making machine by Bradley and Craven Ltd.

BRITISH JEFFERY-DIAMOND LTD.

WE have just received a neat catalogue, No. 1479, obtainable from the Company's offices in Wakefield. It deals with their single roll breakers, flextooth crushers, rigid hammer crushers, swing hammer pulverisers, fine grinders, laboratory grinders, and granulators.

In addition there is a description of their metal turning crushers, swing hammer shredders for fibrous materials such as paper, shavings, wood, etc., and the B. J-D Kibbler.

Electricity as an Aid in the Ceramic Industry

RECENTLY a conference was held under the auspices of the Institution of Electrical Engineers, with the title "Electricity as an Aid to Productivity." A report has now been published by the Institution and may be obtained from the office at Savoy Place, W.C.1 (price 6s. post free).

The following extract from a lecture by O. W. Humphreys, B.Sc., M.I.E.E., entitled "Industrial Heating Processes," will be of interest to the pottery industry:

Electric Firing of Porcelain

The most spectacular success of electric heating from the point of view of saving in time is perhaps to be found in the pottery industry, where, for the firing of porcelain, the traditional and new methods are in use side by side.

The principal processes involved are the pressing of the mouldings, drying, biscuit firing, glazing and glost firing. In the old method, mouldings are prepared in hand presses, drying is carried out on racks in drying rooms and firing in fuel-fired kilns. In order to protect it while in the kiln, the ware is placed in heavy earthenware saggars, which have to be heated along with the ware. The total time occupied for the preparation of a moulding may be as much as 30 days.

Automatic presses are used in the modern method, drying is carried out in radiant heating ovens and firing in a continuous electric kiln. The whole process can be completed in a single day if necessary. Ancillary advantages are that a great deal of space is saved, since the ware can be packed and dispatched so much more quickly; that breakages are reduced, because there is so much less handling; and that, owing to the shorter processing time, production becomes much more flexible.

This brings to an end this review of some of the more important purposes for which electric process heating in one or other of its varied forms can be employed. There must be very few factories in which heating is required which could not simplify their production in some important way, with consequent savings in labour and space and reduction of damage or breakage, by taking advantage of the facilities which are now available. The selection of the method best suited to any particular application is a matter for the expert, but, once installed, the equipment is simple to operate and its benefits are very quickly appreciated. In industry as a whole there is no doubt that electric process heating can make a very major contribution to the increasing of productivity.

Historical Survey

In discussion **Mr. N. Wilson** said: For 2,000 years or more, pottery has been fired in intermittent ovens or kilns using solid or gaseous fuels. The 18th and 19th century ovens were usually cylindrical in shape and ranged in diameter from 10-22 ft. They were fired from the periphery, required great skill to achieve uniform temperatures and produced some of the best pottery the world has ever seen. Unfortunately, the labour of filling and emptying such ovens was wasteful. The skill required to fire them was considerable and costly to achieve. The waste of heat was formidable. In an intermittent oven, without recuperation,

products of combustion must be exhausted at temperatures higher than those of the goods; at maximum temperatures, this may be as high as 1,300° C. The unavoidable heat loss in a coal-fired intermittent kiln, due to this cause, is about 50 per cent. and, since radiation losses often amount to 40 per cent., the actual useful heat employed is about 10 per cent. Of this small amount, 2 per cent. or less is necessary to heat the ware and 8 per cent. is absorbed by the ware containers, called saggars (derived from "safeguard").

Tunnel Kilns

To get over these fundamental difficulties, the tunnel kiln was evolved on the Continent in the early 19th century—and was perfected in muffle form by Conrad Dressler in 1910. In these kilns, ware is placed on trucks insulated with refractories which are propelled slowly through a refractory tunnel of from 50-400 ft. in length. The firing zone is in the middle of the tunnel, and products of combustion pass towards the entrance to heat up the incoming ware. The heat in the fired goods is used to preheat air required for combustion, etc. Tunnel kilns increased the overall fuel efficiency from 10 per cent. to about 20 per cent. halved the labour costs and produced a better and more uniform product—at least, the better ones did.

Electrical firing of pottery started in North Staffordshire in 1926, when Arthur Campbell and Bernard Moore designed a small tunnel kiln for firing on-glaze decorations at temperatures around 700-800° C. The first kiln at Minton's was an immediate success, as was the second, at Wedgewood's. The late Mr. Yeaman, who was electrical engineer for Stoke-on-Trent in those days, deserves much credit for his far-sighted policy in providing electricity at ¾d. per kilowatt-hour for continuous firing. This was reduced to ¼d. in 1939 for biscuit and glost firing.

A few years later, Mr. Odelberg, of Gustavsberg, Sweden, was one of the first to introduce electric glost-firing, using plumbago resistors, and at about the same time, Arthur Campbell of Minton's was successfully firing glost ware at 1,100° C. in a small experimental tunnel kiln at Stoke-on-Trent.

In 1939, Wedgwood's built the first electric tunnel kiln in this country for firing earthenware, biscuit and glost. The kiln is 272 ft. long and consumes some 450 kw. on a biscuit cycle of 70 hours or on a glost cycle of 36 hours. After a few initial troubles, this kiln was a great success and ran without a stop until 1947. A further kiln was built in 1947 to deal with increased output, and this has now been in operation for three years without stoppage. Both kilns are of the counterflow type, a design which uses the heat in one tunnel to compensate for radiation losses in the other.

Tests on First Kiln

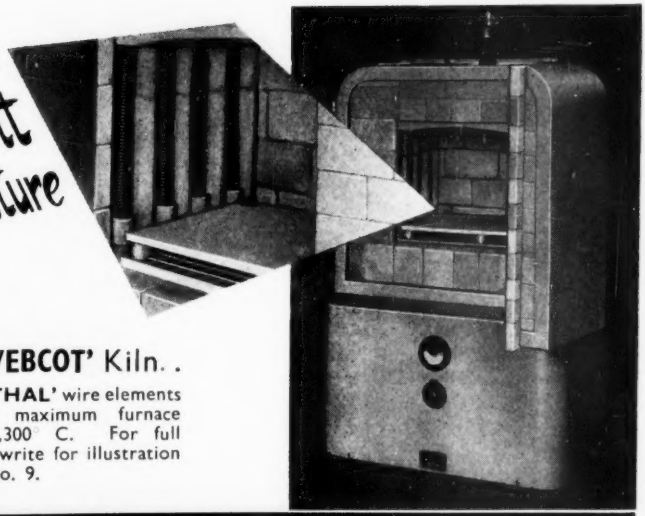
The first kiln was tested by the British Pottery Research Association in 1944, and gave a gross thermal efficiency of 87·3 per cent. compared with an efficiency of 47·9 per cent. for heating the ware alone. The amount of heat required, in therms per ton heated, is much less than with the previous kilns, as will be seen from the following Table:

	Therms per ton	
	Total load	*Ware only*
Electric kiln	19·1	38·7
Best intermittent oven ...	77·0	262·0
Best gas tunnel	40·0	232·0

Measurement showed that firing of china biscuit (at a temperature of 1,260° C.) requires 0·382 kw./lb. consumption whilst earthenware biscuits and glost (at 1,130° C.) can be fired for a consumption of only 0·270 kw./lb.

The quality of ware is superior to any produced by previous methods,

1300°C Constant Temperature



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which include intermittent and tunnel kilns using coal, producer gas, oil and town gas.

Labour costs are reduced to a minimum, and the actual fuel cost per dozen articles fired is lower than it is by any other methods of firing employed in the past, in spite of the relatively high cost of electrical energy (0·7d. per kw.h).

The two counterflow kilns for earthenware and glost employ kanthal elements wound on refractory cores, which can be renewed whilst the kiln is in operation. The kiln temperatures are 1,180° C. for biscuit and 1,080° C. for glost, and each element lasts about 9 months.

In 1948, the first electrically fired china-biscuit tunnel kiln in the world was built at Wedgwood's, for temperatures up to 1,260° C. using globar resistors. This kiln has been in operation for 18 months and is giving very satisfactory service.

No Products of Combustion

Since there are no products of combustion—which are fatal to pottery glaze if they contain sulphur—it is possible to dispense with saggars and to employ lighter "open placing," giving a saving in gross weight of about 75 per cent. and an appreciable saving in volume. Thus, an electric kiln for a given output can be much smaller than any non-electric kiln having to use saggars. This has an important bearing on the capital cost of kiln and factory space, apart from kiln operating costs. Irrespective of the method of placing, the absence of chimney loss and radiation losses due to flues, etc., gives the electric kiln something like a 30 per cent. advantage over kilns employing solid or gaseous fuels. Excessively high flame temperatures are a handicap in most ceramic kilns, and wasteful methods of dilution are necessary if overheating and warping of the product are to be avoided. Electric heating is ideal from this point of view, since automatic temperature control is probably easier with electricity than any

other form of power, whilst labour costs—in terms of supervision and repairs—are very low.

The quality of the final product is almost certain to be higher from a well designed electric kiln than from any other type, owing to the absence of sulphur, dirt and high flame temperatures, coupled with accuracy of control.

With high grade pottery, the yield of saleable articles is much more important than the actual fuel cost per dozen. Thus, electric firing is often a sound economic proposition, even with a slightly higher fuel bill.

With a carefully designed electric tunnel kiln, it is possible to have both a better product and a lower fuel cost per dozen, but this involves a kiln with a fairly high capital cost. If the cost of electricity, which is now two-and-a-half times that of town gas in Stoke-on-Trent, could be reduced, electric firing would receive a corresponding impetus.

The new Wedgwood works was built in 1939 as an "all-electric" factory to provide work and happiness for 800 people. The firm now employs 1,600 persons and the average output per person has increased by 40 per cent. Most of the products go to the United States and Canada. Much has been achieved by a progressive policy, which includes the elimination of drudgery whilst retaining the craftsmanship, and in all this electricity has played a major part.

A FLAW DETECTION PROCESS

UNDER the trade name "Nonfertec," Fel-Electric Ltd., of 41 Sidney Street, Sheffield, are offering a flaw detection technique which has been provisionally patented. The process is based upon the conventional oil and chalk technique, but in this method a water soluble oil is used for soaking the components. The oil is used at room temperature and any excess washed away by cold water, whilst the original chalk has been replaced by a special powder which shows up defects either as red lines or stains.

The company say, the conventional method of using oil and chalk consists of soaking components in an oil bath at approximately 80° C. for 20 min. or more. The oil enters any surface porosity or cracks by capillary attraction. On removal from the bath, any surplus oil is wiped from the surface and, whilst still warm, the component is dusted with french chalk. After standing for some time, defective areas are shown up by the staining of the chalk film due to the seepage of retained oil in cooling.

Difficulties with Large Components

Whilst this technique has previously served more or less satisfactorily for the inspection of components, two major difficulties arose when the process was applied to large components. It proved impossible to wipe the surplus oil from intricate sections in the time taken for the component to cool to room temperature and as a result, considerable masking of defects occurred, due to the spontaneous staining of the chalk on wet areas.

The crack indication, which at best, appeared as a dark grey stain on a light grey background, was not sufficiently defined to make the detection of small cracks infallible, particularly when dark components such as chromated magnesium alloys were being inspected.

In the development of the new Nonfertec method it has been considered necessary to eliminate the need for wiping surplus oil from the surface of components, also some method was desirable where the heating of the oil and the component was reduced or entirely removed. This has now been achieved in the Nonfertec process and the oil is used at room temperature.

It was also thought necessary to have an oil which had the same or better "weeping" characteristics of the conventional oil used in the oil and chalk process and that the oil should be such that the surplus could be washed off by water spray and the component dried in an air blast before application of any powder or chalk.

Efforts were also made to improve the sensitivity of the staining occurring at defective areas and after several methods had been tried, a combination of powder was developed and is now made and mar-

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keted by us under the name "Nonfertec Powder" and which, on application to the component being tested, indicates the faults by means of brilliant red stains, or lines, which are easily visible on the most difficult sections.

The apparatus needed consists of an immersion tank of any material provided that galvanized sheet or lead and zinc linings are avoided. The washing tank should be made of any material and should be fitted with a good water jet, whilst an 80 lb. per sq. in. air-line should be near the tank. Next there is a powder application cabinet, and the powder spray gun completes the equipment.

Process Technique

The process technique itself is as follows:

The water soluble oil for the immersion bath is used at room temperature. The bath is made up of the required amount of oil as supplied by us and must not be mixed with any other materials or oils, or diluted in any way. The powder is supplied by us ready for use. Both the oil and the powder are made to a special formula, under laboratory supervision.

1. Remove all labels, paint and foreign matter from the component.
2. Degrease in trichlorethylene vapour degreaser.
3. Immerse the component (or required portion of the component) in the bath for a period of 10 min.
4. Remove the component from the oil bath and allow the surplus oil to drain back into the tank.
5. Transfer the component to the washing tank and wash off the residual oil by means of the water jet in cold water for a period not exceeding 3 min.
6. Thoroughly dry the component by means of the compressed air jet.
7. Transfer the component to the powder cabinet and apply a fine layer of the dry powder.
8. Transfer the component to the viewing bench and allow to stand for 5 min. to allow any indications to develop.
9. Inspect for surface defects. Suspect areas will be shown by the presence of a red stain, cracks being outlined in red. If a gentle air stream (less than 10 lb. per sq. in.) be directed on to the component, it may assist in revealing the flaws by removing the adjacent unstained powder.

APPOINTMENTS VACANT

CERAMICS. Nelson Research Laboratories, English Electric Co. Ltd., Stafford, invite applications from Chemists and Physicists for vacancies in the Ceramic Laboratory. Applicants should have degree or equivalent qualifications, and be interested in applying scientific principles to the development of electrical and industrial ceramics. Apply giving full details, and quoting ref. 415E to Central Personnel Services, English Electric Co. Ltd., 24/30 Gillingham Street, London, S.W.1.

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CERAMICS. Interesting vacancies with scope for advancement now exist in the Nelson Research Laboratories, English Electric Co. Ltd., Stafford, for development work on industrial ceramics. Applicants should preferably have experience in the development or technical control of electrical porcelains or allied products. Those possessing or studying for the Honours Certificate in Ceramics of the North Staffs Technical College will be given first consideration. Apply giving full details quoting ref. 846B to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1.

ENGLISH ELECTRIC CO. PLANT FOR AUSTRALIA

THE English Electric Co. has been given a contract to supply water turbines and alternators valued at more than £250,000 (Australian) for the Snowy Mountains Hydro-electric scheme.

The plant will be made at Glasgow, and the first will be delivered early in 1953. It will be installed at an altitude of more than 4,000 ft. on the Snowy River.

Announcing the contract the office of the U.K. High Commissioner in Canberra said this was the first of the sixteen power plants for the Snowy scheme, whose total output would approximately equal that of all the power stations feeding Greater London.

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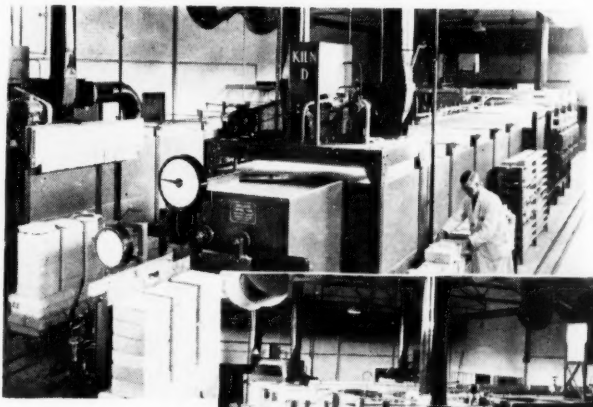

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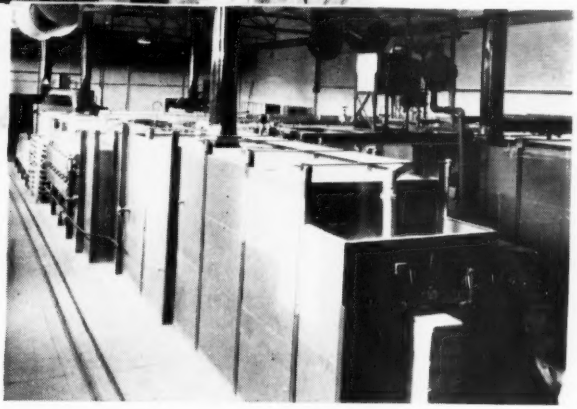

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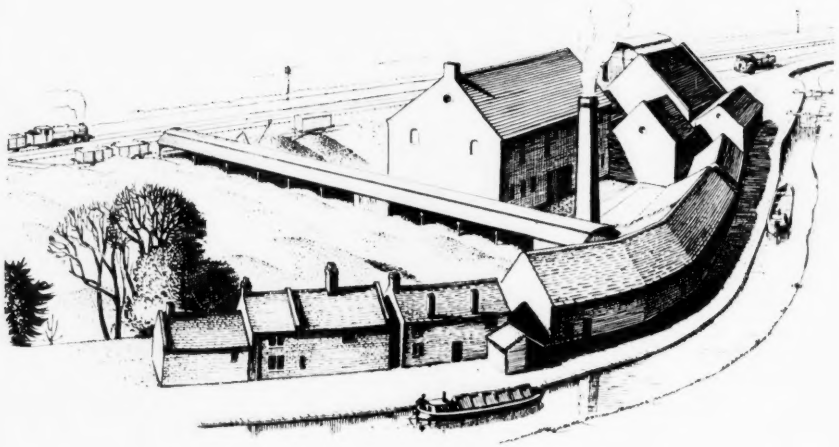

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